Handbook

Softstarter Handbook

Power and productivity
for a better world™

The purpose of this handbook is to provide guidance for correct selection and maintenance of softstarters in industrial installations to ensure a trouble free operation. This without increasing the overall cost.

FOREWORD

This book is written with the thought of being a general guide for people working with softstarter applications but also for those just interested in learning more about this type of starting method. It doesn't matter if you are an expert or novice, hopefully you will find some interesting and useful information either by reading from cover to cover or just the chapters of interest.
The index at the end of the book can be used to simplify your search.

The contents of this book is very much based on the 25 years of experience we have within ABB of developing, manufacturing and selling low voltage softstarters.

The book is not a complete technical guide or manual for all types of ABB Softstarters that may exist on the market. It is a complement to the technical catalogues and brochures we have for our products and will give a general picture of what to think about when working with softstarters.

More information about softstarters as well as other ABB products is available on **www.abb.com/lowvoltage**

All advice given in this book is only general and every single application must be handled as a specific case.

ABB AB,
Cewe-Control
November 2010

Johan Rees　　Magnus Kjellberg　　Sören Kling

ABB will not take any responsibility for any type of faults or damage due to the use of this handbook.

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Standards and approvals

All ABB low voltage softstarters are developed and manufactured according to the rules set out in the IEC (International Electrotechnical Commission).

The IEC issue publications that act as a basis for the world market. The IEC standard for softstarters is called IEC 60947-4-2 and softstarters built according to this standard are in most countries not subject to any other tests besides the manufacturer responsibility. In some countries, law requires certificates.

European Directives

There are three essential European directives:

Low Voltage Directive 206/95/EC

Concerns electrical equipment from 50 to 1000 V AC and from 75 to 1500 V DC.

Machines Directive 2006/42/EC

Concerns safety specifications of machines and equipment on complete machines.

Electromagnetic Compatibility Directive 2004/108/EC

Concerns all devices able to create electro-magnetic disturbance including the level of emission and immunity.

CE Marking

When a product is verified according to its applicable EN standard, the product is presumed to fulfil both the ”Low Voltage Directive” and ”Electromagnetic Compatibility Directive” and it is allowed to use the CE marking on the product. EN 60947-4-2 is the harmonized standard for softstarters and it is identical to IEC 60947-4-2.

In this case, the CE marking does not cover the ”Machines Directive” which will require a special verification of the installation of the machine. Since a softstarter is an electrical device, with mainly electrical risks, it is instead covered by the low voltage directive.

The CE marking is not a quality label; it is proof of conformity with the European Directives concerning the product.

Standards

Specifications in USA and Canada

The specifications for the American and Canadian markets are quite similar, but differ a lot from the IEC standards and European specifications.

USA - **UL** Underwriters Laboratories Inc.

Canada - **CSA** Canadian Standards Association

There are different types of UL certification, among them UL listed and UL component recognition. UL listing means that UL has tested representative samples of the product and determined that it meets UL's requirements. UL's component recognition service, however, only covers the evaluation of components or materials intended for use in a complete product or system. All ABB softstarters that have UL certification, are UL listed.

Softstarters can also be cULus listed, meaning that they are UL listed to US and Canadian safety standards. All the requirements of both UL and CSA are covered by cULus, so the product is then suitable for use in the US and in Canada.

CCC (China Compulsory Certification)

Since the softstarter standard is listed according to the CCC-regulation in China, it is mandatory to have the product approved and labelled with a CCC-mark to be allowed to be put on the Chinese market. The Chinese GB14048.6-2008 standard is based on the IEC-standard IEC 60947-4-2.

Other local approvals based on IEC-standard

In addition to IEC and UL standards, many countries have their own local standards. Some of the major ones besides the already mentioned CSA and CCC are listed below:

GOST – Russia
C-tick – Australia
ANCE – Mexico

Marine approvals

For softstarters used on board ships, maritime insurance companies sometime require different marine certificates of approvals. These can come from BV (Bureau Veritas), GL (Germanisher Lloyd), LR (Lloyd's Register EMEA) which are based on the IEC standard, or from ABS (American Bureau of Shipping) which is based on the UL standard or from some other independent certification organisation. Normally, marine approvals have special requirements regarding shock, vibrations and humidity.

Used standards

Following standards are used or partly used for the softstarters.

IEC 60947-1
EN 60947-1
IEC 60947-4-2
EN 60947-4-2
UL 508
CSA C22.2 No. 14
GB14048.6-2008
LR Test specification No. 1

Definitions, different voltages

Different named voltages are used for the softstarters. The name and use of these different voltages is stated in the IEC-standard (IEC 60947-1) as below.

Operational voltage (U_e),

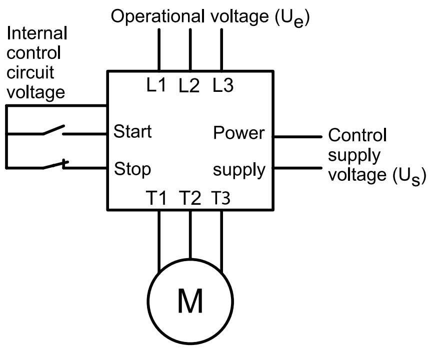
is the voltage feeding the motor and also the voltage exposed to the main circuit (thyristors) in the softstarter. 200 - 690 V AC are normal values.

Control supply voltage (U_s),

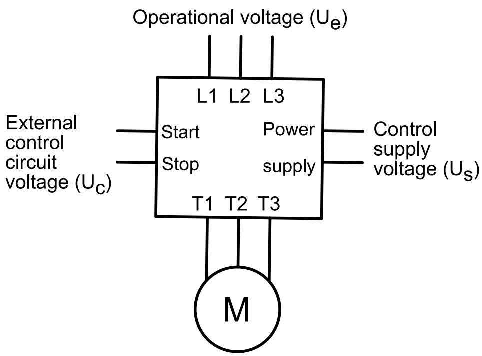
is the voltage feeding the electronic components inside the softstarter, for example the printed circuit board. A common voltage is 100 - 250 V AC.

Control circuit voltage (U_c),

is the voltage for controlling the start and stop command of the softstarter. Common values are 24 V DC or 110 - 240 V AC. On many softstarters, the control voltage can be supplied internally.



Softstarter with internal control circuit voltage



Softstarter with external control circuit voltage

About Motors

Modern electrical motors are available in many different forms, such as single phase motors, three-phase motors, brake motors, synchronous motors, asynchronous motors, special customised motors, two speed motors, three speed motors, and so on, all with their own performance and characteristics.

For each type of motor there are many different mounting arrangements, for example foot mounting, flange mounting or combined foot and flange mounting. The cooling method can also differ very much, from the simplest motor with free self-circulation of air to a more complex motor with totally enclosed air-water cooling with an interchangeable cassette type of cooler.

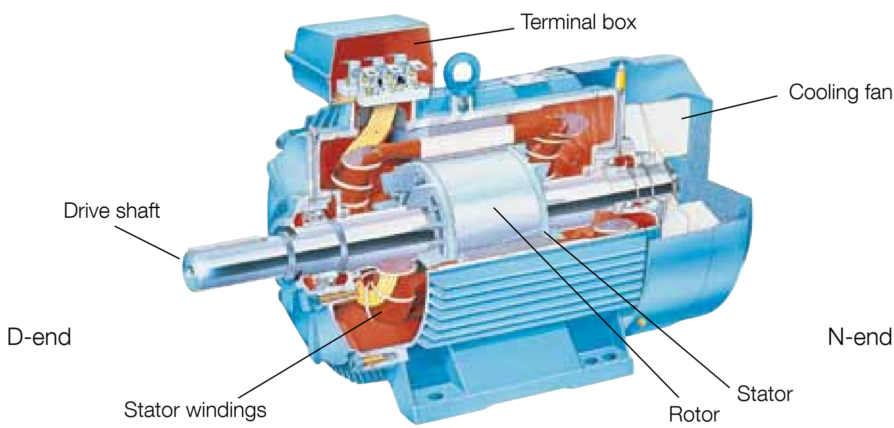
To ensure a long life for the motor it is important to select it with the correct degree of protection when operating under heavy-duty conditions in a severe environment.

The two letters IP (International Protection) state the degree of protection followed by two digits, the first of which indicates the degree of protection against contact and penetration of solid objects, whereas the second states the motor's degree of protection against water.

The end of the motor is defined in the IEC-standard as follows:

- The D-end is normally the drive end of the motor.
- The N-end is normally the non-drive end of the motor.

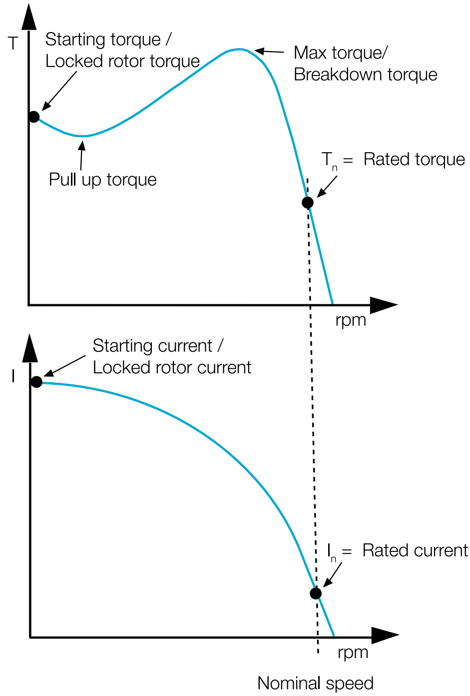
Note that in this handbook we will focus on asynchronous 3-phase electrical motors only.

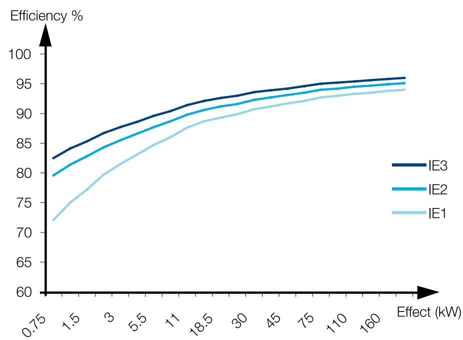


Squirrel cage motors

In this book the focus has been placed on the squirrel cage motor, the most common type of motor on the market. It is relatively cheap and the maintenance cost is normally low. There are many different manufacturers represented on the market, selling at various prices. Not all motors have the same performance and quality as for example motors from ABB. High efficiency enables significant savings in energy costs during the motor's normal endurance. In the standard for rotating electrical machines, IEC60034-30, four different efficiency classes have been defined. The classes are called IE1, IE2, IE3 and IE4, where motors belonging to IE4 are the most efficient ones. See the graph below to the right. The low level of noise is something else that is of interest today, as is the ability to withstand severe environments.

There are also other parameters that differ. The design of the rotor affects the starting current and torque and the variation can be really large between different manufacturers for the same power rating. When using a softstarter it is good if the motor has a high starting torque at Direct-on-line (DOL) start. When these motors are used together with a softstarter it is possible to reduce the starting current further when compared to motors with low starting torque. The number of poles also affects the technical data. A motor with two poles often has a lower starting torque than motors with four or more poles.





Speed

The speed of an AC motor depends on two things: the number of poles of the stator winding and the main frequency. At 50 Hz, a motor will run at a speed related to a constant of 6000 divided by the number of poles and for a 60 Hz motor the constant is 7200.

To calculate the speed of a motor,
the following formula can be used:

$$n = \frac{2 \times f \times 60}{p}$$

n = speed
f = net frequency
p = number of poles

Example:

4-pole motor running at 50 Hz

$$n = \frac{2 \times 50 \times 60}{4} = 1500 \text{ rpm}$$

This speed is the synchronous speed and a squirrel-cage or a slip-ring motor can never reach it. At unloaded condition the

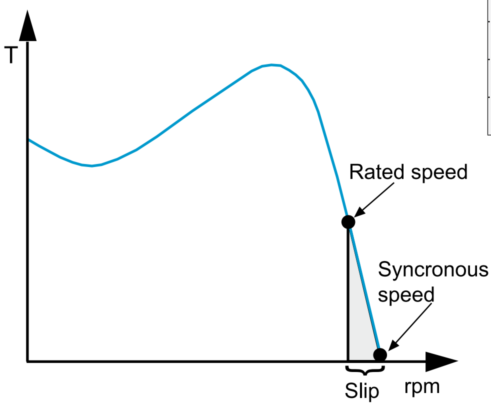


Diagram showing syncronous speed vs.rated speed

speed will be very close to synchronous speed and will then drop slightly when the motor is loaded.

The difference between the synchronous and asynchronous speed also named rated speed is ”the slip” and it is possible to calculate this by using the following formula:

$$s = \frac{n1 - n}{n1}$$

s = slip (a normal value is between 1 and 3 %)
n1 = synchronous speed
n = asynchronous speed (rated speed)

Table for synchronous speed at different number of poles and frequency:

No. of poles	50 Hz	60 Hz
2	3000	3600
4	1500	1800
6	1000	1200
8	750	900
10	600	720
12	500	600
16	375	450
20	300	360

Voltage

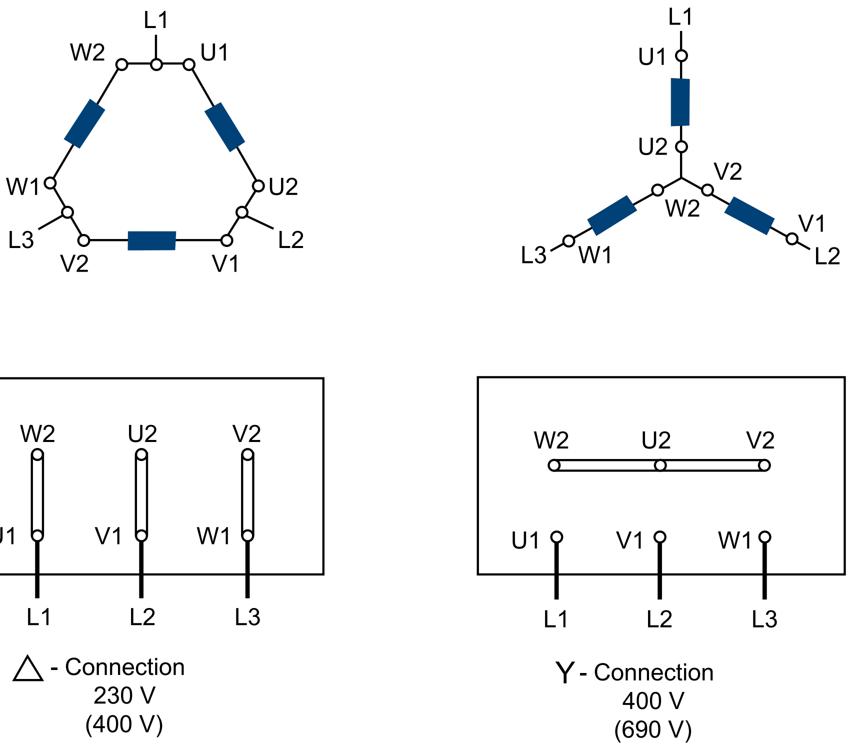
Three-phase single speed motors can normally be connected for two different voltage levels. The three stator windings are connected in star (Y) or delta (D).

If the rating plate on a squirrel cage motor indicates voltages for both the star and delta connection, it is possible to use the motor for both 230 V, and 400 V as an example.

The winding is delta connected at 230 V and if the main voltage is 400 V, the Y-connection is used.

When changing the main voltage it is important to remember that for the same power rating the rated motor current will change depending on the voltage level.

The method for connecting the motor to the terminal blocks for star or delta connection is shown in the picture below.



Picture showing the motor terminal box for a Δ and a Y connected motor

Current

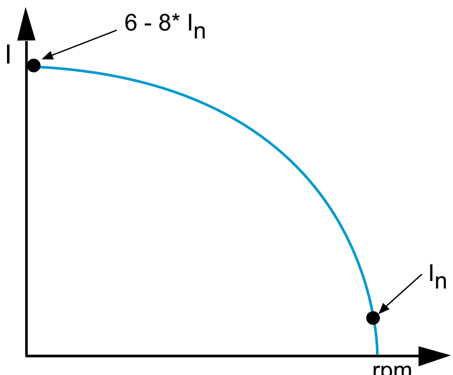
The rated current of the motor, which can be found on the motor nameplate, is the current used by the motor when fully loaded and while up in full speed. An unloaded motor will use far less current and an overloaded motor will use more current.

During direct on line start, the current used by the motor is far higher than the nominal current though. Usually between 6-8 times the rated current, but it can be more than 10 times the rated current. This can be clearly seen in a speed-current diagram for the motor, which can be seen below. As the motor accelerates the current will drop and when reaching the rated speed, the current will have dropped to the rated current.

Power factor

A motor always consumes active power, which it converts into mechanical action. Reactive power is also required for the magnetisation of the motor but it doesn't perform any action. In the diagram below the active and reactive power is represented by P and Q, which together give the apperent power S.

The ratio between the active power P (kW) and the apperent power S (kVA) is known as the power factor, and is often designated as the cos φ. A normal value is between 0.7 and 0.9, when running where the lower value is for small or low loaded motors and the higher for large ones.



Current/Speed curve

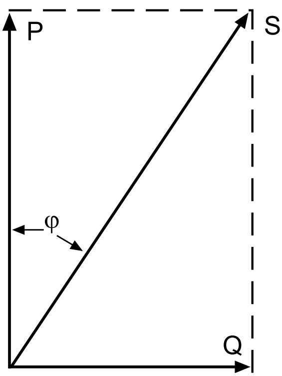


Diagram indicating P, Q, S and Cos ∂

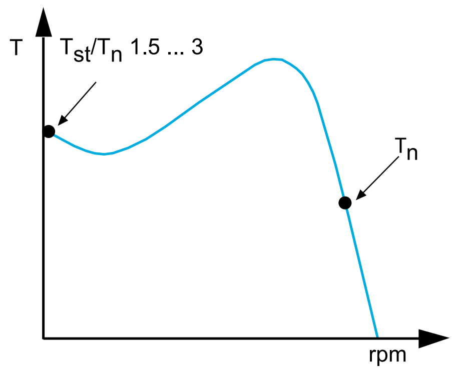
Torque

The starting torque for a motor differs significantly depending on the size of the motor. A small motor, e.g. ≤ 30 kW, normally has a value of between 1.5 and 2.5 times the rated torque, and for a medium size motor, say up to 250 kW. A typical value is between 2 to 3 times the rated torque. Really big motors have a tendency to have a very low starting torque, sometimes even lower than the rated torque. It is not possible to start such a motor fully loaded, not even at DOL start.

The rated torque of a motor can be calculated using the following formula:

$$T_n = \frac{9550 \times P_r}{n_r}$$

T_n = Rated torque (Nm)
P_r = Rated motor power (kW)
n_r = Rated motor speed (rpm)



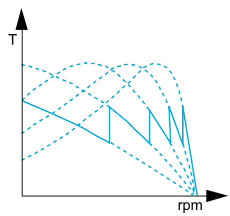
Torque diagram for a typical squirrel cage motor

Slip-ring motors

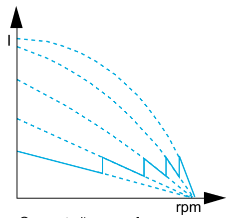
In some cases when a DOL start is not permitted due to the high starting current, or when starting with a star-delta starter will give too low starting torque, a special slip-ring motor can be used. This special motor is started by changing the rotor resistance. When speeding up, the resistance is gradually disconnected until the rated speed is reached and the motor is working at the equivalent rate of a standard squirrel-cage motor.

The advantage of a slip-ring motor is that the starting current will be lower and it is possible to adjust the starting torque up to the maximum torque. But the usage of this starting method is very limited today as both this special motor as well as the rotor starter equipment is very expensive.

In general, if a softstarter is going to be used for this application you also need to replace the motor.



Torque diagram for a slip-ring motor



Current diagram for a slip-ring motor

Different load conditions

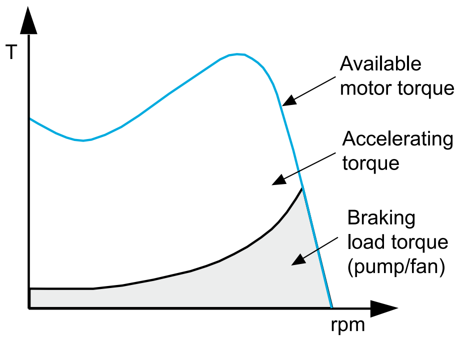
All motors are used for starting and running different applications. The different applications will result in different load conditions for the motor. There are mainly two factors to consider; braking load torque and moment of inertia.

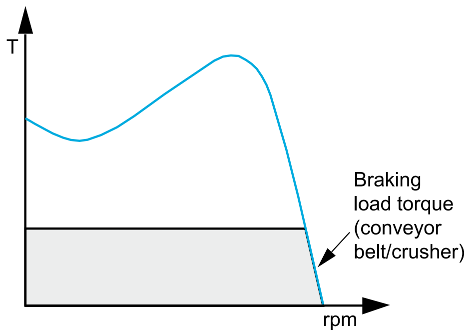
Braking load torque

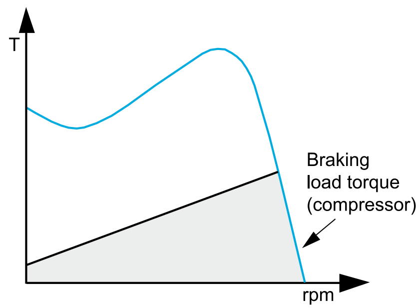
This is a direct braking force on the motor shaft. To be able to accelerate, the motor has to be stronger than the load. The accelerating torque is the difference between the available motor torque and the load toque. Many starting methods will reduce the torque of the motor and thereby reducing the accelerating torque which will give a longer starting time.

Accelerating torque = Available motor torque – Braking load torque.

The load curve can have different characteristic depending on the application. Some of the common load types can be seen below.







Many applications are usually started unloaded, and the load is applied first when the motor has reached the rated speed. This will reduce the load torque to about 10-50% of the load torque of a loaded start.

Moment of inertia

The involved moment of inertia or flywheel mass is the size of the flywheel, connected to the motor axis. An application with a small moment of inertia is usually called a normal start while an application with a big moment of inertia is called a heavy duty start.

Normal start

Small moment of inertia, short starting time, normally OL class 10 is used.

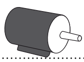
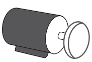
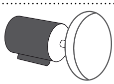
Examples of applications are pumps, compressors, bow thrusters and short conveyor belts.

Heavy duty start

Big moment of inertia, long starting time, normally OL class 30 is required.

Examples of applications are fans, crushers, mills and long conveyor belts.

A bigger moment of inertia will require a longer starting time for the same motor and the same breaking load torque. The table below gives an indication of normal starting times for different load conditions using 3 different starting methods.

	Approximate starting times		
	Direct on line	Star delta starter	Softstarter (ramp time 10 sec)
Motor without load 	0.2 – 0.5 sec	0.4 sec	1 sec
Motor connected to application with small flywheel (normal start) 	2 – 4 sec	3 – 6 sec	6 sec
Motor connected to application with large flywheel (heavy duty start) 	6 – 8 sec	8 – 12 sec	8 – 12 sec

Different starting methods

The following is a short description of the most common starting methods for squirrel cage motors. An overview of common problems when starting and stopping a motor with these starting methods is available on page 20.

Direct on line start (DOL)

Star-delta start

Frequency converter

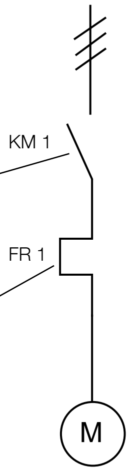
Softstarter

Direct On Line start (DOL)

This is by far the most common starting method available on the market since it is a very compact and a very cheap starting solution. The starting equipment consists of only a main contactor and a thermal or electronic overload relay. The disadvantage with this method is that it gives the highest possible starting current. A normal value is between 6 to 8 times the rated motor current but values of up to 14 times the rated current do exist. There is also a magnetization peak that can be over 20 times the rated current since the motor is not energised from the first moment when starting.

The exact values are dependent on the design of the motor. In general, modern motors have a higher inrush current than older ones because of the lower resistance in the windings.

DOL starter with contactor and O/L relay

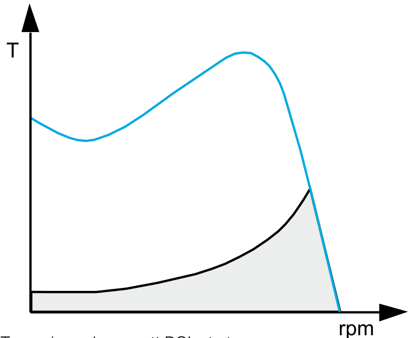


Single line diagram for a DOL starter

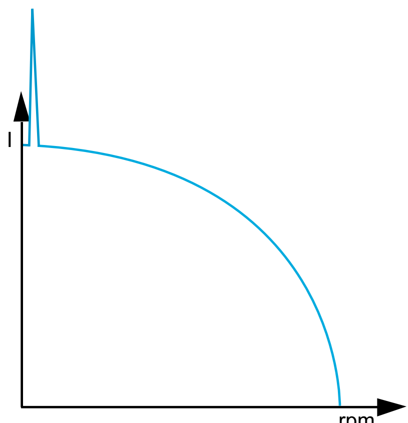
KM 1 Main contactor
FR 1 Overload relay

During a direct on line start, the starting torque is also very high, and for most applications it is higher than necessary. This will cause unnecessary high stress on driving belts, couplings and the driven application. Naturally, there are cases where this starting method works perfectly fine and there is no need to use any other starting method.

If starting DOL, the only possible way to stop the motor is to make a direct stop.



Torque/speed curve att DOL start



Current curve at DOL start

Star-delta start

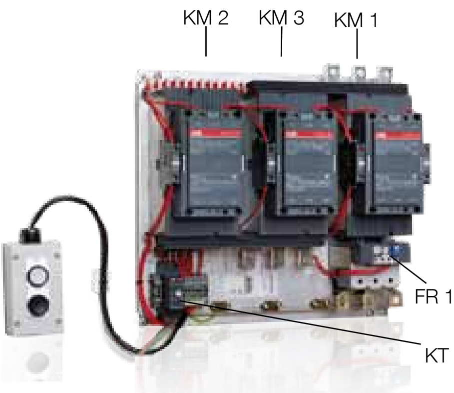
A star delta starter usually consists of three contactors, an overload relay and a timer. This starting method can only be used with a motor that is delta connected during continuous run.

The basic idea behind a star-delta starter is that during the first part of the acceleration, the motor windings are connected in star, giving a reduced current. After a preset time, the connection will change to delta which will give the full current and also the full torque.

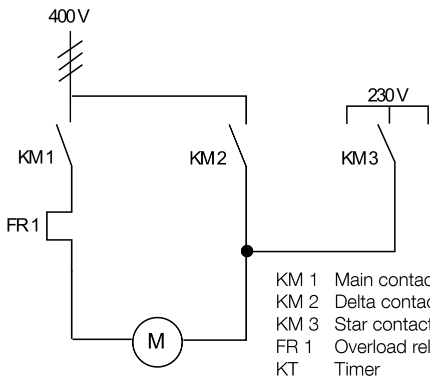
When used in delta, the voltage across each motor winding is same as the network voltage. The motor current will split between two parallel windings with the factor 1/√3 compared to the line current. If the impedance in each motor winding is Z, then the sum of impedance for the parallel windings is Z/√3.

When the motor is star connected (Y- connected) the motor windings become serial connected. The resulting impedance will then be √3*Z, resulting in an impedance which is ((√3*Z)/(Z/√3) = 3), 3 times the impedance when delta connected. As the voltage level is the same, the resulting current when Y-connected will be 1/3 of the current when delta connected. So when starting using Star-Delta start, the star connection results in a current of 33% compared to a delta connected motor.

As the main voltage is the same the motor feels a star connection as a voltage reduction, as because the voltage across each motor windings will be 1/√3 of the main voltage. This lower voltage will also result in a torque reduction. The torque will be reduced with the square of the voltage, [(1/√3)* (1/√3) ≈ 0,33] ending up being 33% of the toque available when delta connected. However, this is only a theoretical value. A more true value is 25% as there are additional losses as well as other efficiency data valid when used star connected. This works well in an unloaded or very light loaded start, but it will not be possible to start heavier applications.



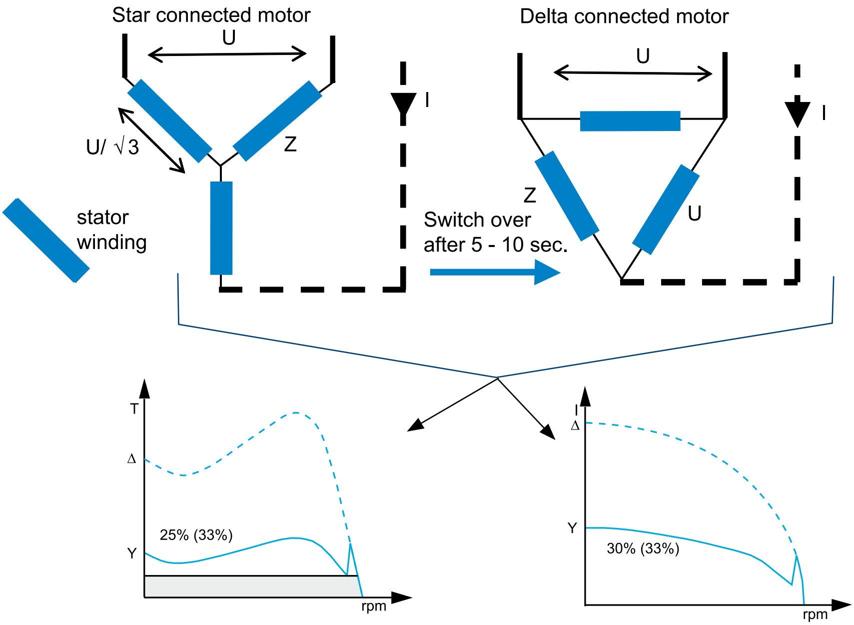
Star-delta starter with contactors and O/L relay



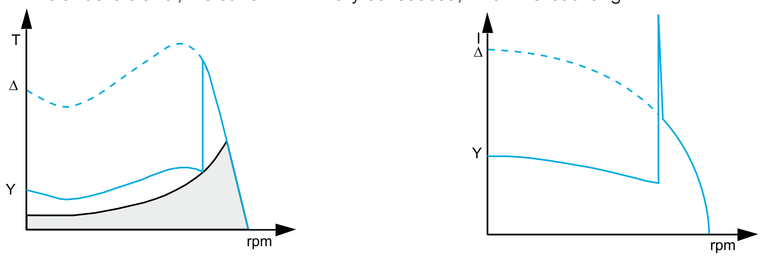
KM 1 Main contactor
KM 2 Delta contactor
KM 3 Star contactor
FR 1 Overload relay
KT Timer

A big problem with star-delta starters appears when starting for instance pumps. The motor will accelerate to about 80-85% of the rated speed before the load torque is equal to the motor torque and the acceleration ceases. To reach the rated speed, a switch over to delta position is necessary, and this switch over will very often result in high transition and current peaks. In some cases the current peak can reach a value that is even higher than for a DOL start.

Also, just as with a DOL start, the only way to stop when using a star-delta starter is to make a direct stop.



With star-delta starter, the current will initially be reduced, when the load is light



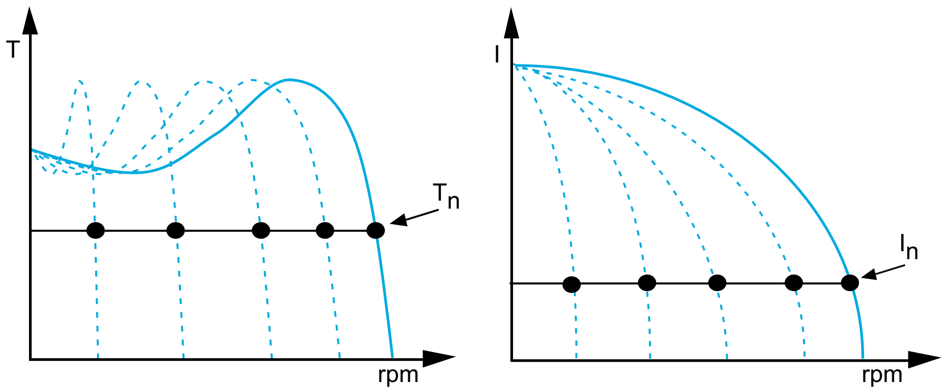
When starting a pump, huge transmission peaks might occur

Frequency converter

The frequency converter is sometimes also called VSD (Variable Speed Drive), VFD (Variable Frequency Drive) or simply Drives. The drive consists primarily of two parts, one which converts AC (50 or 60 Hz) to DC and a second part which converts the DC back to AC, but now with a variable frequency of 0-250 Hz. By controlling the frequency, the drive can control the speed of the motor.

During start, the drive increases the frequency from 0 Hz up to the network frequency (50 or 60 Hz). By gradually increasing the frequency like this, the motor can be considered running at its rated speed for that frequency. Also, since the motor can be considered running at its rated speed, the rated motor torque is available already from start and the current will be around the nominal current. Usually, the drive trips if the current reaches 1.5 times the rated current.

When using a drive to control the motor it is possible to perform a soft stop. This is especially useful when stopping pumps in order to avoid water hammering but it can also be useful for conveyor belts.

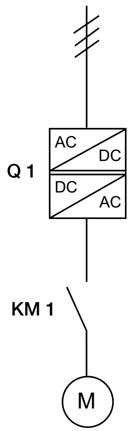


A Frequency converter operates at nominal current and torque even during start.

In many applications it is required to continuously regulate the speed of the motor, and a drive is then a very good solution. However, in many applications a drive is used only for starting and stopping the motor, even though there is no need for continuous speed regulation. This will create an unnecessarily expensive solution if comparing with, for instance a softstarter.

Comparing a softstarter and a drive, the drive has a much bigger physical size and requires more space. The drive is also much heavier than a softstarter making it a less desirable solution on, for instance ships where weight is important. Finally, since the drive changes the frequency and actually creates the sinus wave, a drive will cause harmonics on the network. Additional filters as well as shielded cables are used to reduce these problems but the harmonics will typically not be totally eliminated.

Frequency converter



KM 1 Main contactor
Q 1 Frequency converter

Single line diagram for
a frequency converter

Softstarter

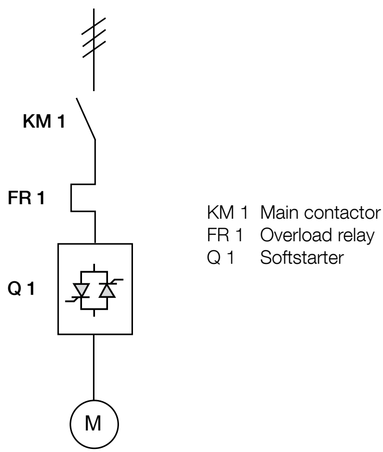
A softstarter does not change the frequency or the speed like a drive. Instead it ramps up the voltage applied to the motor from the initial voltage to the full voltage.

Initially, the voltage to the motor is so low that it is only able to adjust the play between the gear wheels or stretching driving belts etc to avoid sudden jerks during the start. Gradually, the voltage and the torque increase so that the machinery starts to accelerate. One of the benefits with this starting method is the possibility to adjust the torque to the exact need, whether the application is loaded or not.

Using a softstarter will reduce the starting current and thereby avoid voltage drops in the network. It will also reduce the starting torque and mechanical stress on the equipment, resulting in reduced need for service and maintenance.

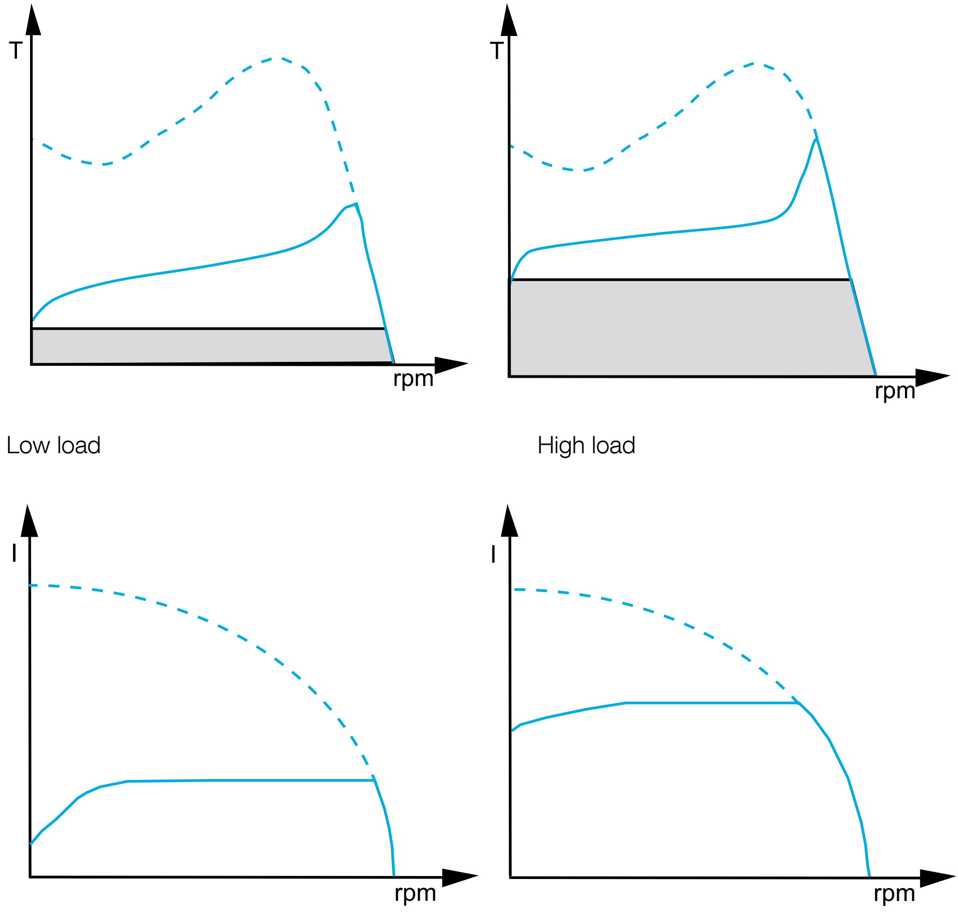
Just as for a drive, the softstarter can perform a soft stop, eliminating water hammering and pressure surges in pumping systems and avoiding damage to fragile material on conveyor belts.

Softstarter



Single line diagram for a softstarter.
The line contactor is not required and sometimes the overload is built-in.*

*) In the PSE and PST(B) softstarters the overload protection is built-in.



Torque and current curves when starting a low loaded motor and fully loaded motor using a softstarter.

Comparision between different starting methods

The table below describes wich problems are provented, using the most common starting methods.

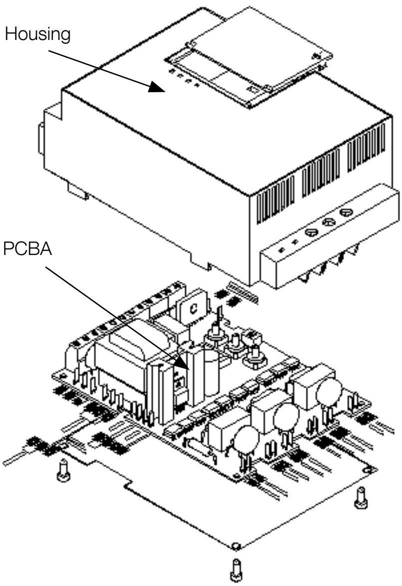
Problem prevented

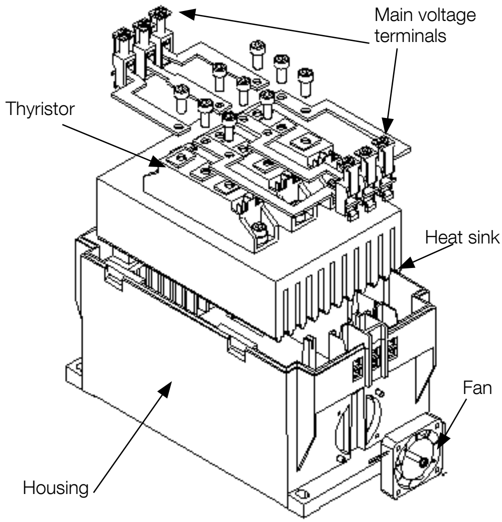
Type of problem	Type of starting method			
	Direct on line	**Star-Delta start**	**Drives**	**Softstarter**
Slipping belts and heavy wear on bearings	No	Medium	Yes	Yes
High inrush current	No	Yes	Yes	Yes
Heavy wear and tear on gear boxes	No	No (at loaded start)	Yes	Yes
Damaged goods / products during stop	No	No	Yes	Yes
Water hammering in pipe system when stopping	No	No	Yes	Yes (Eliminated with Torque control Reduced with voltage ramp)
Transmission peaks	No	No	Yes	Yes
Estimated average installation cost	1	3	> 12	6

General about softstarters

A softstarter consists of only a few main components. These are the thyristors that can regulate the voltage to the motor and the printed circuit board assembly (PCBA) that is used to control the thyristors. In addition to this, there are the heat sink and fans to dissipate the heat, current transformers to measure the current and sometimes display and keypad and then the housing itself. It is more and more common to offer integrated by-pass contacts in the main circuit minimizing the power loss in normal operation.

Depending on the model of the softstarter, it can be equipped with a built-in electronic overload relay (EOL) eliminating the need for an external relay, PTC input, fieldbus communication possibilities etc.





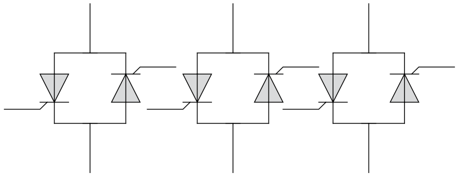
Softstarter functionality

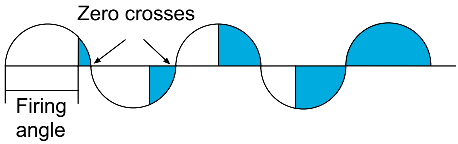
A softstarter consists of a number of anti-parallel thyristors; two in each phase. These thyristors are semiconductor components which normally are isolating but by sending a firing signal, they can start to conduct, allowing the voltage and the current to pass through.

When performing a soft start, a firing signal is sent to the thyristors so that only the last part of each half period of the voltage sinus curve passes through. Then during the start, the firing signal is send earlier and earlier allowing a bigger and bigger part of the voltage to pass through the thyristors. Eventually, the firing signal is sent exactly after passing zero, allowing 100% of the voltage to pass through.

By allowing more and more of the voltage to pass through the thyristors, this can be seen as a ramping up of the voltage from something called the initial voltage to the full voltage.

When performing a soft stop, the opposite happens. At first, the full voltage is allowed to pass through the thyristors and as the stop proceeds, the firing signal is sent later and later allowing less and less of the voltage to pass through until the end voltage is reached. Then no more voltage is applied to the motor and the motor stops.

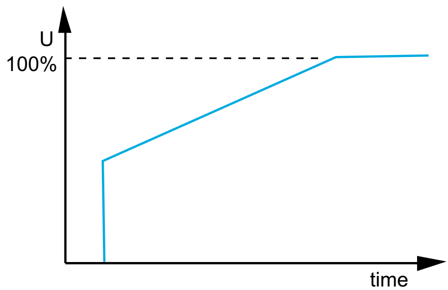




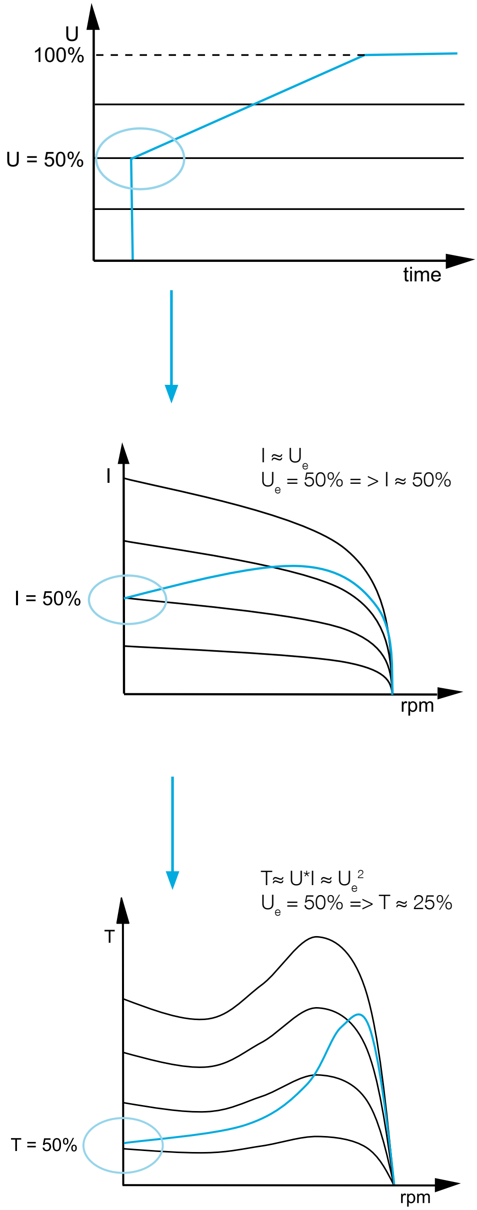
Start: The thyristors let part of the voltage through at the beginning and then increase it, according to the set ramp time for the start.

Stop: The thyristors are fully conducting and when soft stopping, they decrease the voltage according to the set ramp time for stop.

☐ Off : Thyristor is non-conducting
■ On : Thyristor is conducting



Since the voltage to the motor is reduced during the start, both the current and the torque will also be decreased. In fact, if the voltage is decreased to 50% of the full voltage, the current will be decreased to about 50% of the maximum current at that speed and the torque will be decreased to about 25% of the maximum torque.



These are the main benefits of using a softstarter:

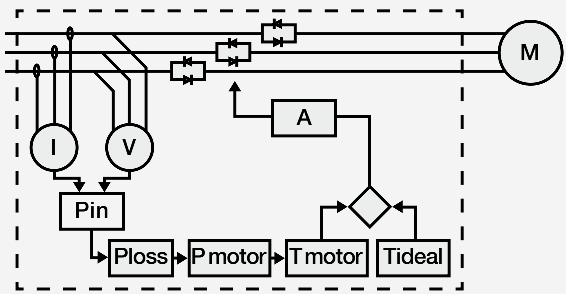
The inrush current is reduced so that voltage drops on the network are avoided. The torque is reduced which will decrease the mechanical stresses on the equipment and lead to a reduced need for service and maintenance and also to a longer life of the equipment. Finally, by using a stop ramp, water hammering is avoided in pump systems, which will further reduce the stress on the equipment.

Torque Control

Normally, a softstarter performs a start and a stop by ramping up or down the voltage linearly. However, a linear change of the voltage does not necessarily give a linear change of the torque or of the speed. This is where torque control comes in. With a torque ramp, it is not the voltage that is ramped up or down linearly, it is the torque. This is done by using a regulation loop where the torque is calculated by measuring both the voltage and the current. This torque is then compared to the required torque and the voltage is adjusted so that the torque is changed in the required way.

Torque control is especially useful for stopping pumps where a sudden decrease of the speed may lead to water hammering and pressure surges that can cause tremendous mechanical wear on the pump, the valves and the pipe system.

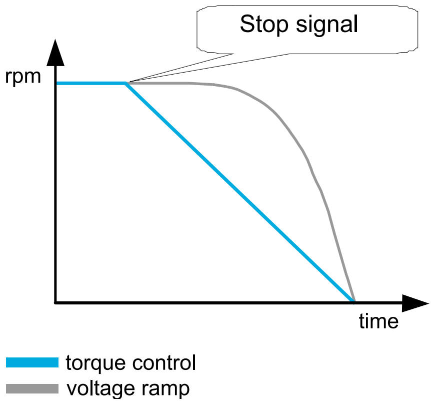
When performing a stop with a normal voltage ramp, the voltage starts to decrease as soon as the stop command is given. However, as the voltage decreases the current will instead increase. This is because the motor will try to remain in its current state. Since the torque depends on both the voltage and the current, it will remain more or less unchanged. Then after some time when the voltage has dropped enough, there will be a sudden drop in the current and the torque and the motor will stop suddenly. This stop will still be far better than a direct stop but in many pump systems this is not good enough, so another solution must be found.



Regulation loop for torque control

With torque control, it is not the voltage that is ramped down – it is the torque. This will force the motor to slow down immediately and perform a controlled deceleration all the way until it comes to a complete stop, see figure to the right.

Being able to have a good control of the torque of the motor is crucial to being able to prevent water hammering. However, this is not enough. What is also needed is a torque curve that has been designed in such a way that the water hammering is avoided. In fact, a linear decrease of the torque is not a very good way to stop a pump. This is why ABB for a long time has worked closely together with pump manufacturers in order to gain knowledge about how to best stop pumps. After more than a thousand different tests and simulations with different combinations of pumps and motors ABB has developed the optimal stopping curve – the perfect way to stop the pump.



Torque control will ensure a more direct effect and a more linear decrease of the speed during stop.

Symbol for torque control.

Softstarters with torque control

Different applications

All motors are used for starting and running different applications. This chapter covers some of the most common ones – fans, pumps, compressors, conveyor belts, crushers and mills. The different applications will result in different load conditions for the motor as described on pages 10-11.

Centrifugal fan

Fans usually have a big moment of inertia due to the big flywheel. Some fans can be started with reduced load torque, with a closed damper. This is called an unloaded start and will make the start easier (shorter) but cause of the high moment of inertia, the starting time might still be quite long.

Direct on line start

The high moment of inertia of fans will lead to a longer starting time. With the high starting current of a direct on line start, this might lead to severe voltage drops in the network, disturbing other equipment.

Centrifugal fans are very often driven by one or more drive belts. During a DOL start these belts have a tendency to slip. The belts slip because the starting torque from the motor is too high during the start and the belts are not able to transfer these forces. This typical problem gives high maintenance costs but also production losses when you need to stop production to change belts and bearings.

Star-delta starter (Y-D)

The star-delta starter gives lower starting torque. However, depending on the fact that the load torque increases with the square of the speed, the motor torque will not be high enough in the star position to accelerate the fan to the rated speed.

When switching over to delta position it will be both a high transmission and current peak, often equal or even higher than values when making a DOL start, with a slipping belt as a result. It is possible to reduce the slip by stretching the belts very hard. But this gives high mechanical stresses on bearings both in the motor and the fan with high maintenance costs as result.

Centrifugal fan

Softstarter

The key to solve the problems with slipping belts is to reduce the starting torque of the motor during start. By using an ABB softstarter the voltage is reduced to a low value at the beginning of the start. Then gradually the voltage is increased in order to start up the fan. The softstarter provides the ability to adjust the settings to fit any starting condition, both unloaded and fully loaded starts. Using a softstarter will also greatly reduce the high inrush current when starting the motor, and thereby avoid voltage drops in the network.

Some softstarters have built-in underload protection which will detect the reduced current caused by a broken belt, and stop the motor to prevent damage.

Selection of a suitable Softstarter

A fan usually has a big flywheel with a big moment of inertia making it a heavy duty start. Select a softstarter one size larger than the motor kW size.

Since the big flywheel of a fan will cause a long slow down period before the fan stops, a stop ramp should never be used for this kind of application.

Recommended basic settings:

Start ramp: 10 sec.
Stop ramp: 0 sec.
Initial voltage: 30 %
Current limit: 4 * I_e

Centrifugal pump

There are a lot of different types of pumps like piston pumps, centrifugal pumps, screw pumps etc. The most common version is the centrifugal pump and this is the one focused on here.

Direct on line start

Starting up a pump is normally not a big problem electrically. The problem is the wear and tear caused by pressure waves in the pipe system created when the motor starts but especially when it stops too quickly. Due to the small flywheel mass and the high breaking torque of a pump, a direct stop will cause a very sudden stop of the pump creating water hammering and pressure surges. During a single stop this is merely an inconvenience but when performing several starts and stops per hour day in and day out, the whole pump system will soon be worn out. This will creat a big need for service and maintenance and even worse unplanned shutdowns.

Centrifugal pump

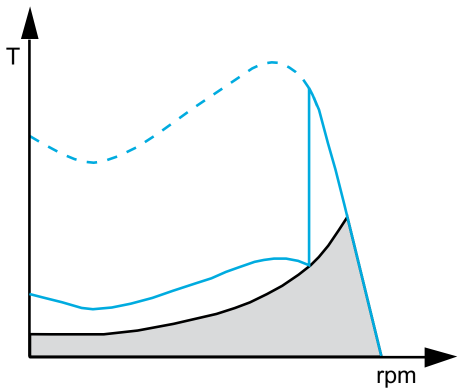
Star-delta starter (Y-D)

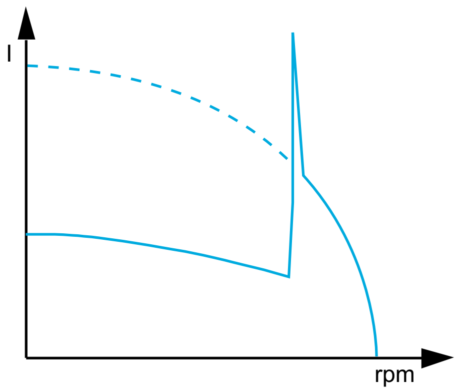
By using a star-delta starter it is possible to reduce the starting torque. However, the motor does not have enough torque in the star position to be able to complete the start and reach the rated speed. The quadratic load torque will become too high for the motor when reaching approx. 80-85% of the rated speed. To continue to accelerate to full speed, a switch over to the delta connection is needed.

When switching to the delta connection, the star contactor is opened and the delta contactor is closed. However, to prevent a short circuit there needs to be a time delay of 50 ms between opening the star contactor and closing the delta contactor. This is enough time for the arc to disappear. Unfortunately, due to the high breaking torque of the pump, the motor will slow down during this period. There will still be a magnetic field in the motor and when the delta contactor closes the difference in potential between the network and the motor might be twice that of the network voltage, reacting up to 800V in an 400V network.

These 800V will create a huge current spike, possibly even higher than the magnetization peak of a DOL start. There will also be a huge torque peak that after several starts might even damage the connections between the motor axis and the load.

In addition, the only possible method of stopping the pump is to perform a direct stop and this will create the same problem with water hammering and pressure surges as for a DOL start.





Softstarter

By using an ABB softstarter the voltage is reduced during the start sequence with the result that the motor torque is reduced. During the start sequence the softstarter increases the voltage so that the motor will be strong enough to accelerate the pump to the nominal speed without any torque or current peaks.

Also during the stop sequence the softstarter is the solution. A softstarter using a normal voltage ramp will for sure reduce the problems with water hammering but in many pump systems this is still not good enough. The solution is to use a softstarter with torque control in order to reduce the torque and stop the motor in the most optimal way in order to totally avoid water hammering.

In addition, some softstarters are equipped with underload protection to detect pumps running dry, with kick start to start blocked pumps and with locked rotor protection to prevent damage caused by pumps being jammed while running.

Selection of a suitable softstarter

A pump usually has a very small pump-wheel with a low moment of inertia. This makes the pump a normal start so the softstarter can be selected according to the kW rating. If more than 10 starts per hour are performed it is however recommended to upsize the softstarter one size.

Recommended basic settings:

Start ramp: 10 sec.
Stop ramp: 10 - 20 sec.
Initial voltage: 30 %
Stop mode: Torque control
Current limit: 3.5 * I_e

Compressor

Smaller compressors are often of the piston type and the load torque increases linearly with the speed. Screw compressors are often used when there is a bigger need for air flow and this type has a load torque increasing with the square of the speed. Drive belts are often used between motor and compressor but direct connections via some type of toothed couplings are also common. Most compressors are started unloaded.

Direct on line start (DOL)

Compressors started direct on line are exposed to high mechanical stresses on the compressor itself, but also on drive belts and couplings. The result is shortened endurance. In cases where the drive belts are used the belts very often slip during the start. The source of these problems is the high starting torque occurring with the DOL method.

Star-delta starter (Y-D)

Star-delta start gives a lower starting torque and starting current but the motor is too weak during the start up to be able to accelerate the motor up to nominal speed. When switching to the delta position both current and torque peaks will occur with high mechanical stresses as a result.

Softstarter

By using an ABB softstarter it is possible to limit the starting torque to a level suitable for all different applications. The result is less stress on couplings, bearings and no slipping belts during start. The maintenance cost will be reduced to a minimum. When using a softstarter the starting current received is approx. 3 to 4 times the rated motor current.

Selection of a suitable softstarter

A compressor is usually a normal start and then the softstarter can be selected according to the motor kW size. If the compressor is a heavy duty start, the softstarter should be upsized one size. The same applies if more than 10 starts per hour are performed, upsize one size.

Recommended basic settings:

Start ramp: 5 sec.
Stop ramp: 0 sec.
Initial voltage: 30 % (piston compressor)
40 % (screw compressor)
Current limit: 3.5 * I_e

Conveyor belt

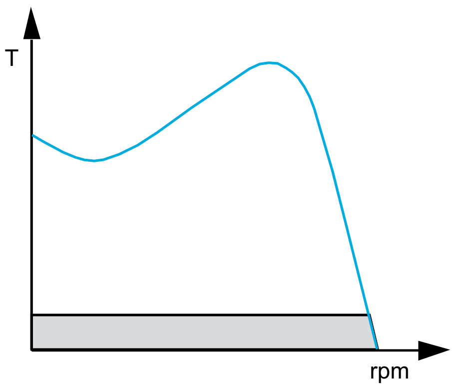
Conveyor belts can have a lot of different characteristics. The length can vary from only a few meters up to several kilometres and the belt can be horizontal or inclining. Typically, the conveyor belt has a constant load torque with low to high braking torque depending on the load.

Direct on line start (DOL)

Conveyor belts often need a starting torque very near or just above the rated torque of the motor. A direct on line start with a normal squirrel cage motor gives approx. 1.5 to 2.5 times rated torque of the motor depending on motor size, type etc. When making a direct on line start there is a very high risk of slipping between the belt and the driving role depending on this high starting torque. Gearboxes and couplings are also exposed to high mechanical stresses. This result is considerable wear and tear and often high maintenance costs.

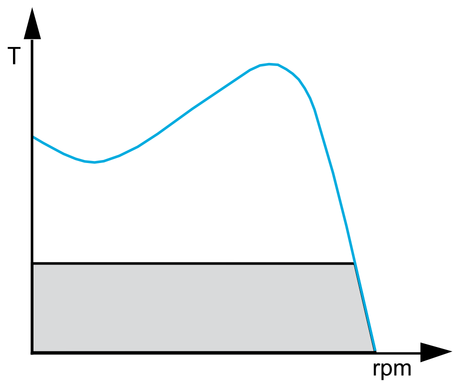
Sometimes fluid couplings are used to reduce the transferred torque. This method is expensive and requires a lot of maintenance.

Low braking torque



Torque/speed curve at DOL start

High braking torque

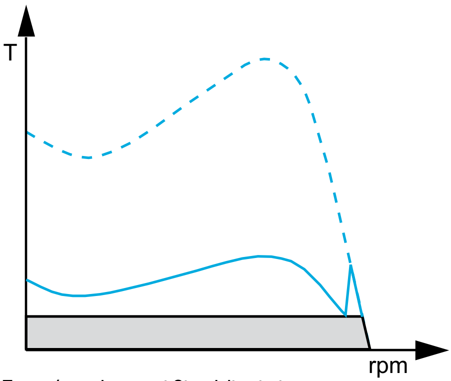


Torque/speed curve at DOL start

Star-delta start

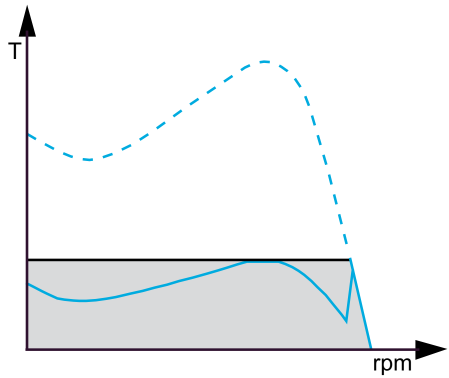
Since the start delta starter will reduce the torque in the star connection, it is not possible to use this starting method when the load torque is close to the rated motor torque during start. A star delta starter can only be used successfully with a very lightly loaded conveyor belt.

Low braking torque



Torque/speed curve at Star-delta start

High braking torque



Torque/speed curve at Star-delta start

Conveyor belt

Softstarter

By using an ABB softstarter the starting torque can be reduced to a minimum value and still be able to start up the conveyor belt. The setting feature of the softstarter makes it possible to adjust the torque to exactly the level that is necessary for the start. The result is the least possible stress on gearboxes and couplings and no slipping belts during the start. This will reduce the maintenance cost to a minimum. When using a softstarter you will receive approx. 3 to 4 times rated motor current during the start.

In addition, some softstarters are equipped with phase reversal protection to detect conveyor belts running in the wrong direction. Softstarters may also have under- or overload protection to detect if the load is too low or too high, and then kick-start to be able to start jammed belts.

Selection of a suitable softstarter

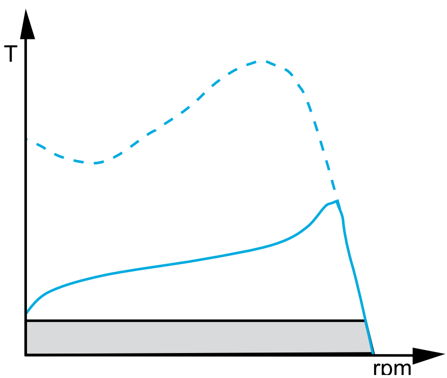
A conveyor belt can be both a normal start and a heavy duty start depending on the characteristics. For a normal start, select the softstarter according to the motor kW rating. For a heavy duty start, select one size bigger.

If more than 10 starts per hour are done, select one size bigger softstarter.

Recommended basic settings:

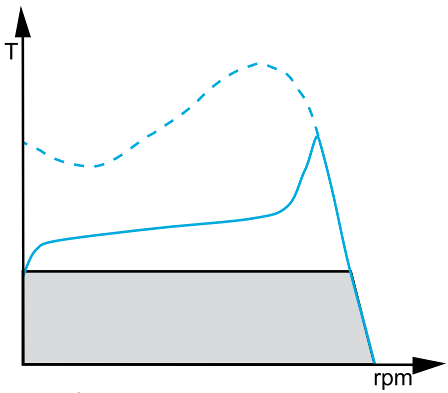
Start ramp: 10 sec.
Stop ramp: 0 sec.
(If fragile material use 10 seconds)
Initial voltage: 40 %
Current limit: $4 * I_e$

Low braking torque



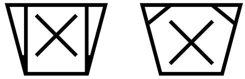
Torque/speed curve when using a softstarter

High braking torque



Torque/speed curve when using a softstarter

Crusher and Mill



Crushers and mills usually have constant load curves. These applications can have a very big flywheel and can be a very heavy duty start. In most cases, both these applications are started unloaded, and when full speed is reached, the load is applied.

Direct on line start (DOL)

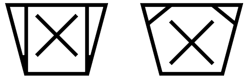
When starting direct on line there will be high mechanical stresses leading to a shortened life length for all parts of the drive chain. In addition, the inrush current will be high and as a result of this in combination with the long starting times, there might be big disturbances in the network.

Star-delta starter (Y-D)

Applications such as these are often started unloaded, and it will then be possible to start with a star delta starter. Loaded starts on the other hand will require a high torque of the motor, so such starts are not possible with a star delta starter.

Even though these applications normally are started unloaded, there may be occasional loaded starts, for instance if an emergency stop has been performed on a crusher. The material is then still in the crusher and it must be started with the load already applied. Under such circumstances, a star-delta starter may not be a feasible option.

Crusher and Mill



Softstarter

By using an ABB softstarter it is possible to limit the starting torque to a level suitable for all different load conditions. The result is less stress on the machinery and greatly reduced inrush current. For an unloaded start the inrush current can be reduced to approximately 3 times the current while a loaded start may require 5 times the nominal current.

Selection of a suitable softstarter

Crushers, mixers, mills and stirrers usually have a very big moment of inertia so the softstarter is selected one size larger than the motor kW size. For extremely big flywheels, the use of Prosoft selection program is recommended.

Since the big flywheel will cause a long slow down period before the fan stops, a stop ramp should never be used for this kind of application.

Recommended basic settings:

Start ramp: 10 sec.
Stop ramp: 0 sec.
Initial voltage: 30 % - 60%
Current limit: 3-5 * Ie

How to select a softstarter for different applications

It is normally possible to select a softstarter according to the rated motor power. In some cases it is neccessary to select a larger softstarter than the rated motor power depending on the starting conditions (heavy duty start, many starts/h etc.) The starting capacity of a softstarter is very much depending on the thyristor capacity and the heat sink.

The table below can be used as a guide to select a softstarter if you need a quick answer and you want to be sure that the size is large enough to suit the application. This selection will however not give the most optimized solution. If an opimised solution is required, the software selection program ”ProSoft” for selection of softstarters can be used, available on **www.abb.com/lowvoltage**. For more information see page 45.

Quick guide for selection

Normal start	**Heavy duty start**
Selection Select the softstarter according to the rated motor power. For units with built-in overload, select trip class 10.	**Selection** Select one size larger softstarter compared to the rated motor power. For units with built-in overload, select trip class 30.

Typical applications

Normal start		Heavy duty start	
• Bow thruster	• Centrifugal pump	• Centrifugal fan	• Conveyor belt (long)
• Compressor	• Conveyor belt (short)	• Crusher	• Mill
• Elevator	• Escalator	• Mixer	• Stirrer

If more than 10 starts/h

! Select <u>one</u> size larger than the standard selection

Ambient temperature

The ambient temperature is the average surrounding temperature of the softstarter over a period of 24 hours. For most types of softstarter the temperature may not exceed 40 ^{O}C without derating the operational current for the unit.

The maximum ambient temperature during operation differs from one type of softstarter to another and must be checked individually according to the manufacturer's specification.

When using an ABB softstarter with an ambient temperature of above 40 ^{O}C, the following formula can be used to calculate the operational current:

I_e derated	=	$I_e - (\Delta T \times I_e \times 0.008)$
I_e derated	=	maximum operational current after derating
I_e	=	rated current of the softstarter
ΔT	=	temperature difference
0.008	=	derating factor

Example 1

Rated current: 105 A
Ambient temperature: 48 ^{O}C
Derating with 0.8 % per ^{O}C above 40 ^{O}C
(PST(B)30 ... 1050)

ΔT = 48-40 ^{O}C = 8 ^{O}C
New current = $I_e - (\Delta T \times I_e \times 0.008)$ =
105 - (8 x 105 x 0.008) = 98.2 A

This means that a PST105 can only be used for 98.2 A. For a 105 A motor, a larger PST needs to be used.

Example 2

Rated current: 300 A
Ambient temperature: 46 ^{O}C
Derating with 0.8 % per ^{O}C above 40 ^{O}C
(PST(B)30 ... 1050)

ΔT = 46-40 ^{O}C = 6 ^{O}C
New current = $I_e - (\Delta T \times I_e \times 0.008)$ =
300 - (6 x 300 x 0.008) = 285.6 A

This means that a PST300 can only be used for 285.6 A. For a 300 A motor, a larger PSTB needs to be used.

Derating when used at high altitudes

When a softstarter is used at high altitudes the rated current for the unit has to be derated, due to less cooling. For most manufacturers the catalogue values are valid up to 1000 m above sea level before derating is necessary.

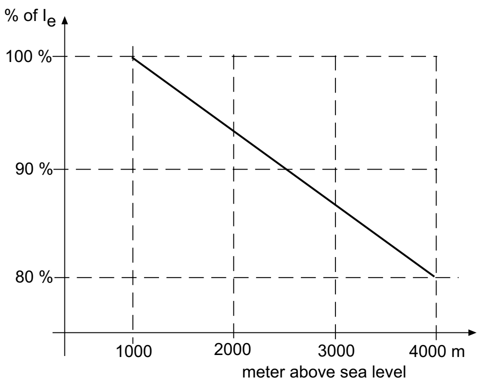
In some cases a larger softstarter is required to be able to cope with the motor current when used at high altitudes.

For ABB softstarters the following formula can be used for calculating the derating:

$$\% \text{ of } I_e = 100 - \frac{x - 1000}{150}$$

x = actual altitude for the softstarter

The diagram below can also be used for defining the derating of the softstarter.



Derating of motor current at high altitudes

Example:

Softstarter with rated current 300 A used at 2500 meter above sea level.

$$\% \text{ of } I_e = 100 - \frac{2500 - 1000}{150} =$$

$$= 100 - \frac{1500}{150} = 90$$

$I_e = 300 \times 0.9 = 270$ A

This means that a PST300 can only be used for 270 A. For a 300 A motor, a larger PSTB needs to be used.

Starting capacity and overload protection

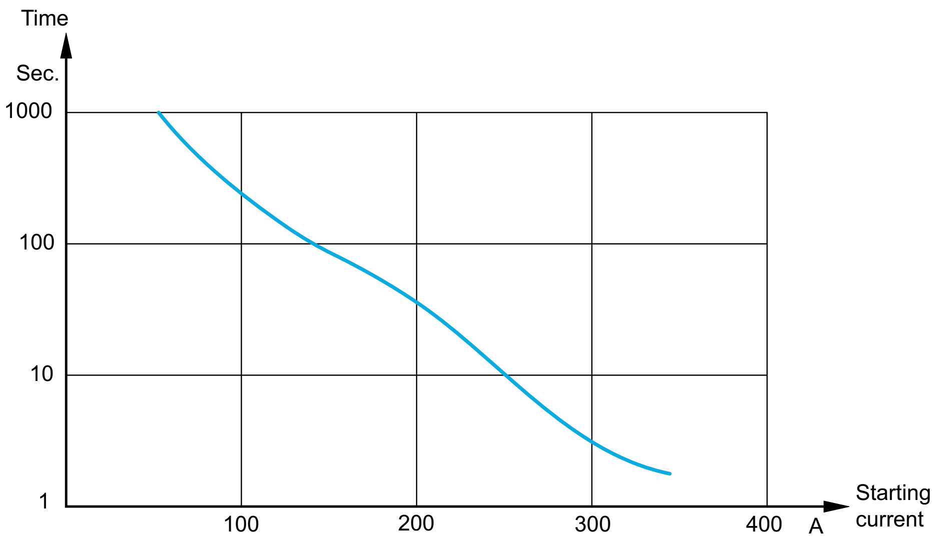
Starting capacity for softstarters

When starting a squirrel cage motor there will always be a starting current (I_{st}) which is higher than the rated motor current. When starting DOL this starting current is typically 7-8 times the nominal current and when using a softstarter it is reduced to 3-5 times the nominal current.

Depending on the application, the start can be short or long. Since the current is higher during the start the softstarter will warm up during the start. It is very important to select a softstarter with thyristors and heat sink dimensioned for the motor and the start performed. The softstarter should be upsized one size when used for heavy duty applications since the start then usually is longer.

The maximum permitted starting current for a softstarter depends on the starting time. The ratio between the current and time is displayed in the starting capacity graph below.

The voltage or current to the motor is not affected by selecting a bigger softstarter. The only difference when selecting a bigger softstarter is that the softstarter is dimensioned to cope with a higher current for a longer time and thus being able to start bigger motors or heavier applications.

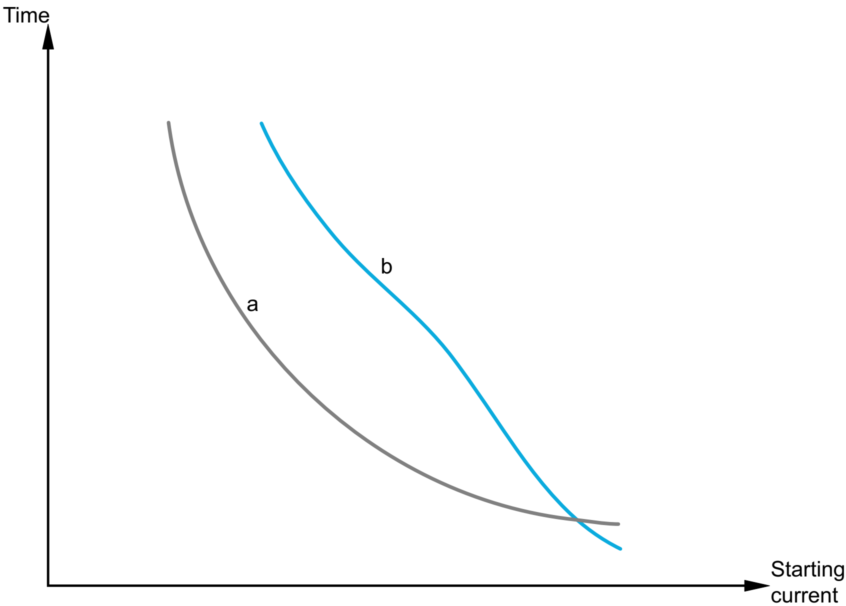


Typical starting capacty graph for a softstarter

Starting capacity when using overload protection

The overload protection for the motor (thermal or electronic) will very often set the limit of the starting capacity. These overload protections have different tripping classes, describing how fast they are tripping for a specific current. A class 10 relay is used for normal starts in general while a class 30 relay is used for heavy-duty starts where the start usually is longer.

In some applications where the overload protection is by-passed (other protection active) during a start to achieve a longer available starting time, it is particularly important to check the softstarter starting capacity since this will be the limitation.



a) Tripping curve for overload protection
b) Max starting capacity for a softstarter (This will limit the starting time / current if the overload is by-passed during start)

Number of starts per hour

The maximum number of starts/hour for a softstarter depends on several different factors such as the starting current, ambient temperature, starting time and the intermittens factor.

Intemittens factor

The intermittens factor is a figure indicating how long the softstarter has been running for (starting time and running time) compared with the total cycle time.

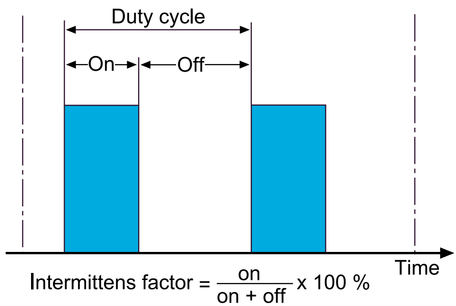
It is important to define the intermittens factor when talking about the number of starts/hour since the OFF time is the cooling time for the softstarter.

A high starting current and a long starting time require a longer OFF time than a low starting current and short time to maintain the same number of starts/hour.

Examples:

If a softstarter has been running for 5 minutes of a total duty cycle of 10 minutes then the intermittens factor is 50 % ON time and 50 % OFF time.

If a softstarter has been running for 45 minutes of a duty cycle of 60 minutes then the intermittens factor is 75 % ON time and 25 % OFF time.

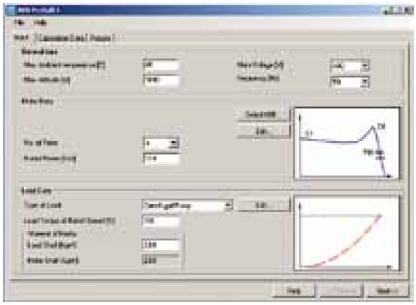


Prosoft

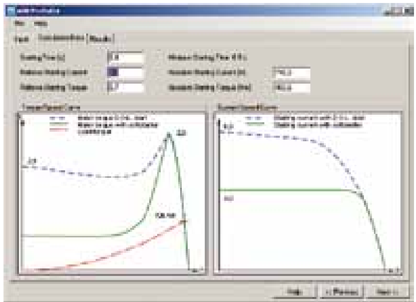
The selection of a softstarter can be done according to the softstarter main catalog. This will work fine in the majority of cases but by using the softstarter selection tool ProSoft, a more optimized selection will be achieved. Especially in extremely heavy duty applications with several minutes starting time, the use of ProSoft is recommended.

When using ProSoft, the selection is done in 3 steps, which can be seen as 3 different tabs in the program:

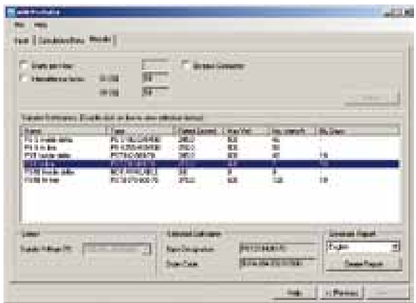
1. Input tab – Type in the general data and information about the motor and about the load. Try to use as accurate data as possible to get the most accurate results.



2. Calculation tab – Here it is possible to see how long the start will be depending on how high the current is. This tab will indicate which settings should be used and it might affect the selection.



3. The selection tab – Select which of the suggested softstarters to use. Here it is also possible to generate a report containing all information about the selection.



Different ways of connecting the softstarter

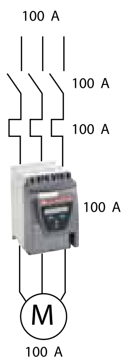
There are two different ways of connecting the softstarter - In line, which is the most common method, and Inside Delta. Not all softstarters can be connected inside delta however. The ABB PSE range and PSR range can only be connected In Line.

In-line connection

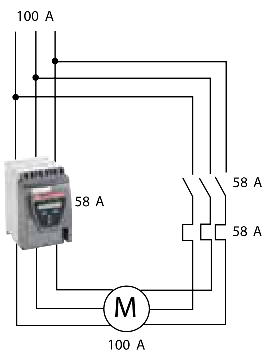
This is the most common and also the easiest way to connect the softstarter.

All three phases are connected in series with the overload relay, the main contactor and other devices used just like the diagram below. The selected devices for Inline connection must be chosen to cope with the full rated motor current. The motor itself can either be star connected or delta connected

Example: 100 A motor requires a 100 A softstarter, 100 A main contactor etc.



Softstarter connected
In-line with the motor



Softstarter connected
Inside Delta

Note: In the PSE and PST(B) softstarters the overload protection is built-in.

Inside Delta connection

The Inside Delta connection makes it possible to place the softstarter in the delta circuit and allows for a very easy replacement of existing star delta starters.

When the softstarter is Inside Delta it will only be exposed to 58% ($1/\sqrt{3}$) of the In-line current. Therefore it is possible to downsize the devices in order to achieve a more cost-effective solution.

All functionality will be identical regardless if connecting in line or inside delta. However, with the inside delta connection, 6 cables are required between the softstarter and the motor, and if this distance is long, an in line connection might be a more cost efficient solution.

Example: A 100 A motor requires a 58 A softstarter, a 58 A main contactor if placed in the delta circuit, etc.

A motor used for an Inside Delta connection must be able to delta-connect during a continuous run. In the USA and some other countries a special six-wire motor has to be ordered for this type of connection.

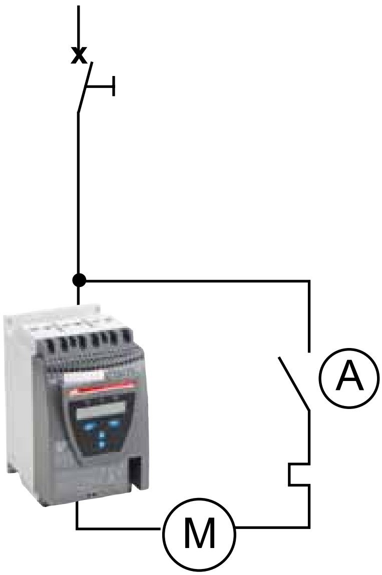
A softstarter controlling the voltage in only two of the three phases can not be used inside the motor delta.

Location of the main contactor

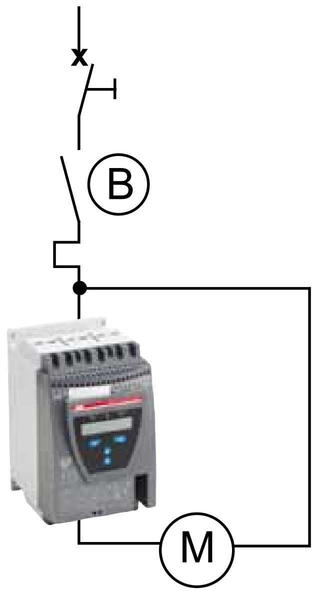
When using the softstarter Inside Delta, there are two options for the main contactor; inside the delta circuit or outside. Both locations will stop the motor but in alternative A, the motor is still considered to be under tension.

In alternative B, the main contactor must be chosen according to the rated current of the motor, while the contactor in alternative A can be chosen according to 58% ($1/\sqrt{3}$) of the rated current.

Regardless of where the main contactor is placed, it should be AC-3 rated for that current, to be able to break the current and stop the motor in an emergency.



Alternative A
Main contactor located in the delta circuit



Alternative B
Main contactor located outside the delta circuit

Note: In the PSE and PST(B) softstarters the overload protection is built-in.

Start of several motors

In some applications, it is desirable to start several motors with one softstarter, in parallel with each other or in a sequence. This is often possible to do but some data has to be taken into consideration.

Parallel start of motors

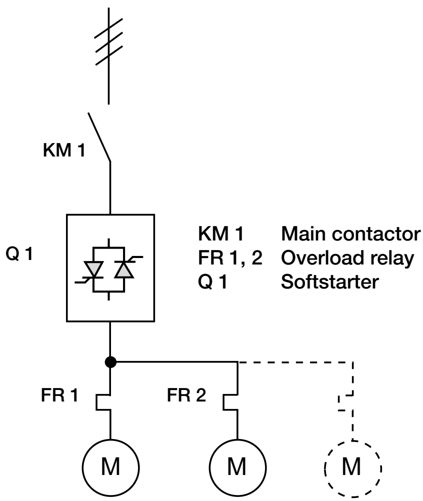
If a softstarter is going to be used for starting several motors at the same time (parallel start), there are two important parameters to check:

1. The softstarter must be able to cope with the rated current for all motors together.
2. The softstarter must be able to cope with the starting current for all motors together until rated speed is achieved.

> **Note!**
> **If a by-pass contactor is used for the softstarter, only point 2 above has to be taken into consideration.**

Example:

Start of two motors with Ie = 100 A and relative starting current 4 x Ie.
Starting time is 10 seconds.
Total starting current is 100 x 4 x 2 = 800 A for 10 seconds.
Check the softstarter starting capacity graph to verify the selected size.
Make sure that you are using separate overload relays, one for each motor.



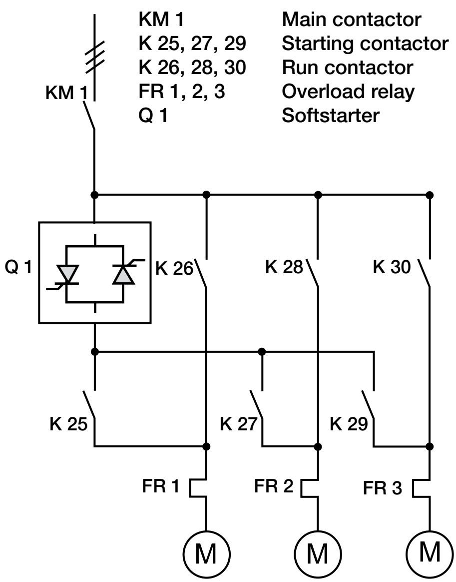
Parallel start of motors using a softstarter

Sequential start of motors

If a softstarter is going to be used for starting several motors one by one (sequential start), it is important to check that the softstarter is able to cope with the starting current for each motor during the whole starting sequence.

Example:

Start of three motors with Ie=100 A and relative starting current 4 x Ie.
Starting time for the motors is:
Motor 1 = 5 seconds
Motor 2 = 10 seconds
Motor 3 = 8 seconds



Sequential start of motors using a softstarter

The starting current for the motors is 100 x 4 = 400 A and the total starting time is 5 + 10 + 8 = 23 seconds.
Check the softstarter starting capacity graph to verify the selected size.

> **Note!**
> **It is not possible to add the starting time for each motor if the rated current is different from one motor to another. A separate calculation has to be made for those applications.**

Some softstarters, like the PST(B) range, have the possibility to use different parameter sets for the different motors. This is needed to achieve a good start if the motor sizes are different or if the applications are different.

Most softstarters can not softstop more than the latest started motor.

Usually, separate protections need to be used for each of the motors.

Connection of control circuit

Control supply

The control supply voltage is the voltage supplied to the circuit board, fans etc in the softstarter. The terminals are usually marked 1 and 2. A common voltage is 100-250V AC.

Functional earth

On softstarters with a functional earth, this shall be connected to the mounting plate, using an as short cable as possible. This will ensure the most reliable operation of the softstarter.

Control circuit

The control circuit is used to give a start and stop signal to the softstarter and sometimes to give other input signals. Depending on the softstarter, the control voltage may be taken from the softstarter itself or may be supplied externally. Most often the control voltage is 24 V DC. Also depending on the softstarter model, the signals required may need to be maintained or it may be enough with a pulse.

Output signal relays

There are sometimes up to three different output signals that can be received from the softstarter. See table below.

Analog output

Some softstarters are equipped with an analog output signal that can be connected to an analog meter or be used as an analog input to a PLC. The analog output can be used to see the current to the motor on an analog current meter, eliminating the need for an external current transformer.

For connection diagrams, see www.abb.com/lowvoltage.

Run	Closes as soon as a start signal is given and remains closed all the time when the softstarter is feeding voltage to the motor. Usually used to control a line contactor.
TOR / By-pass	Closes when the softstarter reaches top of ramp (full voltage fed to the motor) and remains closed until a stop signal is given. Usually used to control an external by-pass contactor.
Event	This relay will close (or open) when any fault or protection occurs. Can be used to signal an error or to open a line contactor.

Common output signals relays on softstarters.

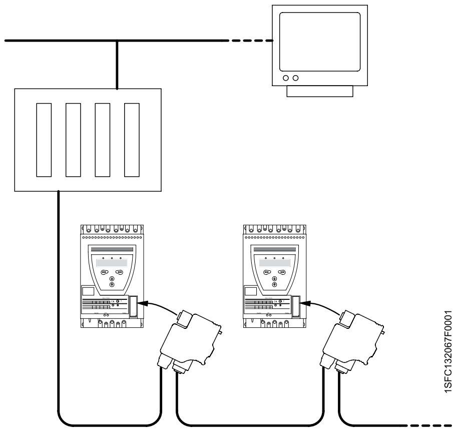
Connecting a softstarter to a fieldbus system

Connection

Today, many softstarters can be connected to a PLC using a fieldbus system such as Profibus or Modbus. Depending on the softstarter and the fieldbus protocol it may be possible to start and stop the softstarter, to see status information and to change the settings of the softstarter from the PLC. To connect an ABB softstarter to a fieldbus system, the FieldBusPlug is used. Just select the plug that matches the protocol used. An overview of the connection is showed to the right. For more detailed information about connection, see the manual for the corresponding fieldbus protocol, avaliable at www.abb.com/lowvoltage.

Software files

For most of the fieldbus protocols, a special software file is needed when programming the PLC. The table below explains which files are required for the different protocols. It is very important to make sure that the software file used, matches the softstarter version. For each version of the software file there is also one corresponding manual to explain the information that can be sent. Both the software files and the manuals are available at www.abb.com/lowvoltage.



Fieldbus protocol	Type of file	Versions
Profibus	gsd-file	The latest version of the gsd-file supports all softstarter versions. Same file supports both DP/V0 and DP/V1
Modbus	No software file needed	–
DeviceNet	eds-file for DeviceNet	The version of the software file must match the version of the softstarter.
CANopen	eds-file for CANopen	The version of the software file must match the version of the softstarter.

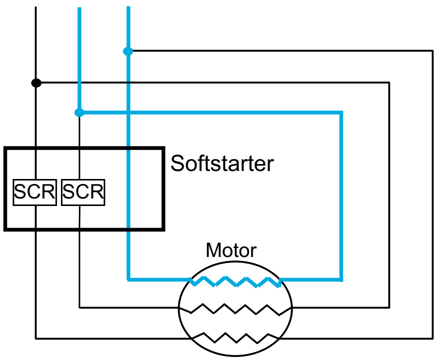
2-phase control vs 3-phase control

Traditionally, a softstarter havs used 6 thyristors, two antiparallel connected in each of the three phases, to control the output voltage to the motor. However, in order to reduce the number of components used and to minimize the size of the softstarter, a solution where only 2 of the 3 phases are controlled is possible. In this solution, the third phase is just passing through the softstarter without controlling the voltage or the current. A softstarter controlling only 2 of the 3 phases is called a "2 phase controlled softstarter" and it will function in the same way as a 3-phase controlled softstarter with a few exceptions described below.

Not possible to connect Inside Delta

Since one of the phases is not controlled by the softstarter, the current would pass through that phase without giving a start signal to the softstarter. This would not start the motor but it would heat up the motor and eventually damage the motor.

Even if a line contactor would be used to avoid this during stand by, the curent would basically not be reduced at all when starting, and reducing the current perhaps the most important benefit of using a softstarter.

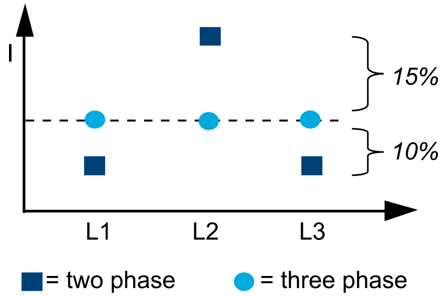


Some 2-phase controlled softstarters create a DC-component

When ramping up and down by controlling only 2 phases, a DC-component will be created which will have a breaking effect reducing the torque and creating a very noisy bad start. Only very few 2-phase controlled softstarters on the market, including those from ABB, are equipped with sophisticated algorithms to eliminate this DC-component. It is a must to have access to this special algorithm to be able to design 2-phase controlled softstarters for larger motors.

Slightly unbalanced currents during start

When using a 3-phase controlled softstarter, the starting current will be balanced between the three phases. When using a 2-phase controlled softstarter, however, the current will be higher in the phase that is not controlled and lower in the other two phases. This has the effect that the maximum current (in one phase) is higher with a 2-phase controlled softstarter compared with a 3-phase controlled softstarter. This unbalance will only appear during the short time of the start and the stop. During continuous run, the currents will be balanced.



When is 2-phase controlled softstarter a good solution?

A 2-phase controlled softstarter works good:

- In most normal applications
- In all different segments
- When torque control is required
- Normal start or heavy duty start
- When a compact and cost efficient solution is required

A 3-phase controlled softstarter is preferred when:

- The absolutely lowest starting current is required
- Inside delta connection is required
- The unbalanced currents during start and stop is a problem

2-phase controlled softstarters

3-phase controlled softstarters

Settings

This section includes a short description of some of the most important setting parameters available on softstarters. Not all of these settings are available on all softstarters and other settings may be available depending on the type of softstarter and manufacturer. The settings can be done either by adjusting potentiometers, changing dip switches, using a key pad, a computer or similar.

Start ramp is the time from were the softstarter starts its ramp (initial voltage) until full voltage is reached. The ramp time should not be too long, as this will only result in unnecessary heating of the motor and a risk of the overload relay tripping.

A common misunderstanding is that this parameter sets the start time, that is the time for the motor to reach full speed. This is not true. The start ramp parameter only sets the time until the softstarter applies full voltage to the motor. If the motor is unloaded, the start time for the motor will probably become shorter than the set ramp time. And if the motor is heavily loaded, the start time will probably become longer.

Stop ramp is used when a soft stopping of the motor is required, for example, a pump or a conveyor belt. The stop ramp is the time from full voltage until end voltage is reached. If the ramp time is set to zero the stop will be like a direct stop.

Torque control is a function that will control the torque of the motor instead of the voltage. This is especially useful when stopping pumps in order to avoid water hammering. On softstarters with torque control it is possible to select between a torque ramp or a voltage ramp both during start and stop. These parameters are called start mode and stop mode.

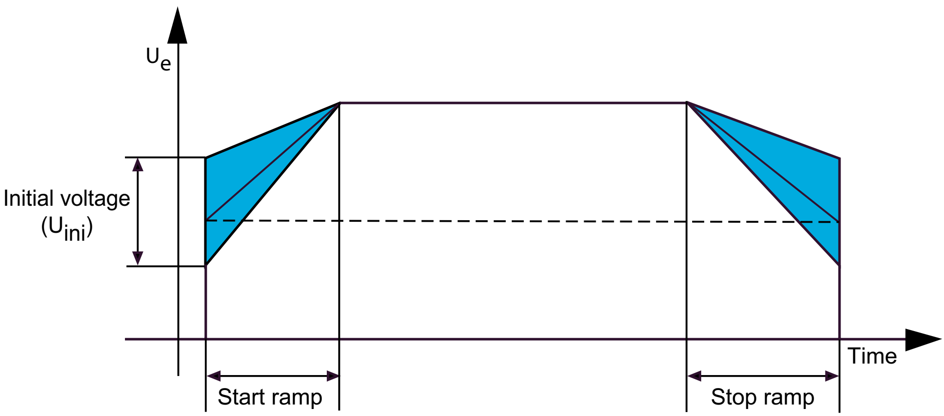


Diagram showing start ramp, stop ramp and initial voltage

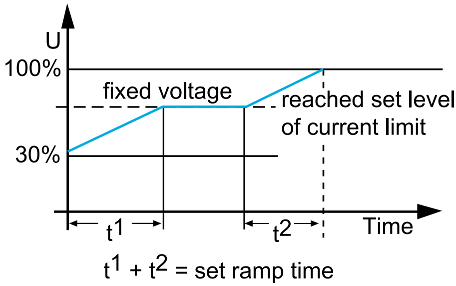
Initial voltage is sometimes named pedestal voltage. This is the point from where the softstarter starts to ramp up. The torque of the motor will drop with the square of the voltage and if the voltage is set too low, for example 20 %, the starting torque will become $0.2^2 = 0.04$ = 4 % only, and the motor will not start from the very beginning. Therefore, it is very important to find a level that is just high enough to make the motor take off directly to avoid unnecessary heating.

End voltage is the voltage level that the softstarter ramps down to during the set ramp time of a stop ramp. At this point the motor shall already have stopped and the softstarter will break the current to the motor in order to avoid unnecessary motor heating.

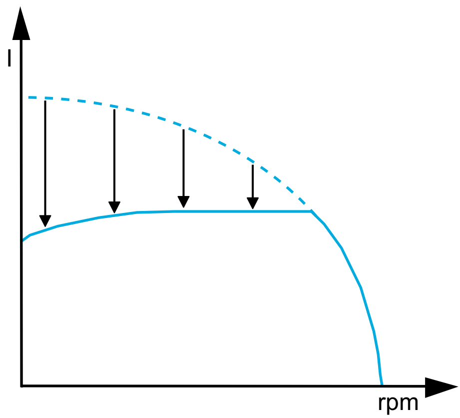
Adjustable rated motor current makes it possible to set the motor rated current on the softstarter for the used motor. This setting will affect other values as well, such as the trip level of the electronic overload protection and other protections, but also the level of the current limit function.

Settings

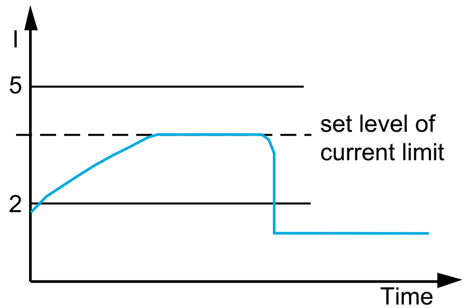
Current limit can be used in applications where a limited starting current is required, or at a heavy-duty start when it is difficult to achieve a perfect start with the setting of the initial voltage and the start ramp only. When the current limit is reached, the softstarter will temporarily stop increasing the voltage until the current drops below the set limit, and then continues ramping up to full voltage. Since the maximum current (DOL-current) is decreasing as the speed increases, the voltage can be gradually increased without exceeding the set current limit



Holding the voltage at a fixed level will keep the current on the set level



The current and voltage needs to be reduced more in the beginning of the start.



Current limit function in a softstarter limits the current to the pre-set level

Recommended settings

The required settings for the softstarter will differ from one application to another depending on the type of load, motor characteristics, how much the motor is loaded, etc. The settings on these pages are only general recommendations so for each installed softstarter the settings should be checked individually.

When using a 2-phase controlled softstarter, the initial voltage and current limit might need to be set slightly higher.

Recommended settings when using a softstarter

Type of load	Ramp time for start (sec.)	Ramp time for stop (sec.)	Initial voltage U_{ini} (%)	Current limit (x I_e)	Torque Control for stop (if available)
Axial fan	10	Off	30	4.0	Off
Band saw	10	Off	30	4.0	Off
Bow Truster	10	Off	30	1.5 – 3	Off
Centrifugal fan	10	Off	30	4.0	Off
Centrifugal pump	10	10 – 20	30	3.5	On
Circular saw	10	Off	30	4.0	Off
Compressor	5	Off	30	3.5	Off
Conveyor belt	10	Off	40	4.0	Off
Crusher	10	Off	30	4.0	Off
Cutter	10	Off	30	4.0	Off
Escalator	10	Off	30	3.5	Off
Grinder	10	Off	30	4.0	Off
High pressure pump	10	10	50	4.5	On
Hudraulic pump	10	Off	30	3.5	Off
Lift/Elevator	10	Off	30	3.5	Off
Mill	10	Off	30	4.0	Off

Explosive atmospheres (Ex)

For plants in environments where the hazard of explosion is due to an explosive mixture of gases, explosive matter or combustible dust other than explosive dust, special provisions are applicable regarding the use of electrical material.

The different classes of explosive protection (Ex) are described by the following parts of IEC 60079:

IEC 60079-1:	flameproof enclosures ”d”
IEC 60079-2:	pressurised enclosures ”p”
IEC 60079-5:	powder filling ”q”
IEC 60079-6:	oil immersion ”o”
IEC 60079-7:	increased safety ”e”
IEC 60079-11:	intrinsic safety ”i”
IEC 60079-18:	encapsulation ”m”
IEC 60079-22:	caplights for mines susceptible to firedamp (under consideration)
Example: Electrical apparatus for explosive atmospheres - oil immersion ”o” shall be recognised as Exo	

Hazardous areas and zones

The hazardous areas are categorised in zones as follows:

Zone 0

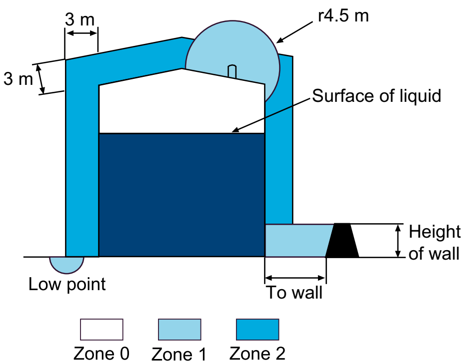
An area in which an explosive gas atmosphere is present continuously or for long periods. Only intrinsically-safe circuits of category Exi may be used in this zone. Motors are thus excluded.

Zone 1

An area in which an explosive gas atmosphere is likely to occur in normal operation. Motors of category Exd, Exe and Exp may be used in this zone.

Zone 2

An area in which an explosive gas atmosphere is not likely to occur during normal operation and if it does occur it will exist for a short period only. Equipment permitted in zones 0 and 1 may of course be used. Under certain conditions the equipment, motors for example, need not to be of explosion-protected design.



Example of classification and extent of the hazardous area in a tank

ATEX

ATEX means ATmosphere EXplosible and describes what equipment and work environment is allowed in an environment with an explosive atmosphere. It consists of two EU directives:

- the ATEX 95 equipment directive 94/9/EC, Equipment and protective systems intended for use in potentially explosive atmospheres.
- the ATEX 137 workplace directive 99/92/EC, Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

Location and selection of softstarter for Ex environments

If a softstarter is going to be used for an Ex application it is normally located in a separate enclosure outside any of the hazardous zones. The overload relay used shall be of a special version designed for Ex motors, for example TA25DU ... V1000 to T900DU/SU...V1000. As well as a special version of the product UMC. This type of relay has a more accurate tripping curve compared with the standard relay. Special attention has to be paid to this.

The softstarter type and size and other devices used in the circuit is suitably selected according to type 2 coordination.

Note!
If any electrical equipment is going to be used in any of the hazardous zones, a special enclosure must be used. This type of enclosure (steel box or similar) must be able to withstand an inside explosion caused by any of the components without letting anything out to the surroundings. This solution is in general very unusual.

Coordination

By coordination we mean a selected combination of electrical apparatus which are safe for the surroundings and personnel, even if an overload or a fault should occur in the system.

The coordinated group must ensure the following four essential functions:

- Protection against overloads. A protection, which guards all components, cables and the motor from overheating, active for all currents up to, locked rotor current. This device will send a trip signal to a disconnection mean, which is normally a contactor used for the motor control.
- Motor control. This function is commonly carried out by a contactor.
- Protection against short-circuits, which takes care of all currents above the locked rotor current - i.e. all fault currents.
- Isolation. Ensure an isolating air-gap when opened for personnel safety.

The coordinations for the ABB softstarters are done according to IEC 60947-4-2 ”AC semiconductor motor controllers and starters” and EN 60947-4-2.
The provisions of IEC 60947-1, General Rules, are applicable to IEC 60947-4-2 where specifically called for.

The standard IEC 60947-4-2 defines two types of coordination according to the expected level of service continuity.

Type 1:
Coordination requires that, under short-circuit conditions, the device shall cause no danger to persons or installation and may not be suitable for further service without repair and replacement of parts.

Type 2:
Coordination requires that, under short-circuit conditions, the device shall cause no danger to persons or installation and shall be suitable for further use. For hybrid controllers and starters, the risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken as regards the maintenance of the equipment.

Note!
When using a softstarter in a type 2 coordination, replacing the fuses and restart has to be accepted after a short-circuit. Only semi-conductor fuses can be used to achieve a type 2 coordination for a softstarter.

Utilization Categories

Some utilization categories are stated in the standard IEC 60947-4-2, ”AC semiconductor motor controllers and starters”. The one used for ABB Low Voltage softstarters is AC-53, since this is about controlling squirrel cage motors. This is the category stated in the header of the coordination tables for softstarter.

Utilization Category	Typical application	Remark
AC-53a	Control of squirrel cage motors: 8 h duty with on-load currents for start, acceleration, run	Softstarter designed for use without external by-pass contactor
AC-53b	Control of squirrel cage motors: intermittent duty	Softstarter designed for use with external by-pass contactor.

Note!
Some ABB softstarters have built-in by-pass while others do not have this. However, it is never required to add an external by-pass contactor, since all ABB softstarters are designed according to AC-53a utilization category.

Types of protections

There are several different types of protection for electrical devices used on the market. They all have different functions and characteristics. One type cannot in general replace another type without checking the other protection devices in the circuit. If replacing a 100 A fuse with another 100 A fuse (same rating) without checking the type then there is a risk of losing protection. The first type may be a type with both short-circuit protection and thermal protection while the replacement fuse is a type with only short-circuit protection.

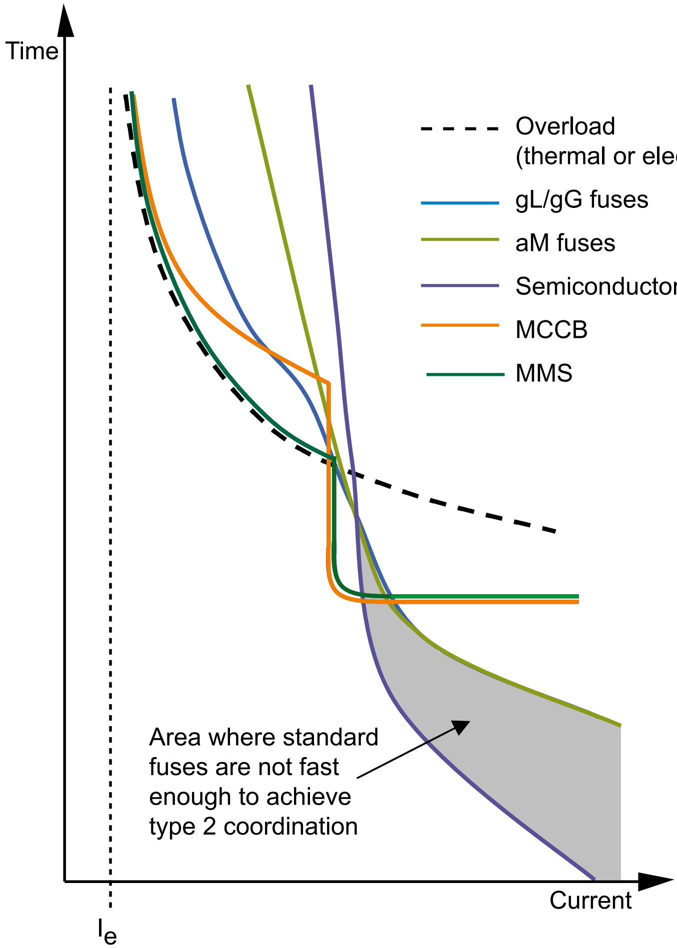
gL/gG fuses have a combination of short circuit protection and thermal overload protection (5s > 3,5 x In) for cables. Type 1 coordination can be achieved if using these types of fuses together with a softstarter. For type 2 coordination, semiconductor fuses must be used.

aM fuses only have a short-circuit protection (5s > 9 x In). For thermal overload protection, a separate protection device is required. Type 1 coordination can be achieved if using these types of fuses together with a softstarter. For type 2 coordination, semiconductor fuses must be used.

MCCB means Moulded Case Circuit Breaker and is a breaker usually providing both thermal overload protection and short circuit protection. Using a MCCB, type 1 coordination can be achieved. For type 2 coordination, semiconductor fuses must be used.

MMS means Manual Motor Starter and is a device consisting of isolation function, thermal overload protection and short circuit protection. Manual motor starters are available up to about 100 A. Using a MMS, type 1 coordination can be achieved. For type 2 coordination, semiconductor fuses must be used.

Semi-conductor fuses (High speed fuses) are the only type of fuses that are fast enough to achieve a fully type 2 coordination when using a softstarter. A separate overload relay for the motor protection is always required in combination with this type of fuse. If replacing the semi-conductor fuses with an MCCB, MMS or similar, type 1 coordination will be achieved instead.


Time
Overload
(thermal or electronic)
gL/gG fuses
aM fuses
Semiconductor fuses
MCCB
MMS
Area where standard
fuses are not fast
enough to achieve
type 2 coordination
Current
I_e

Coordination tables

The coordination tables for softstarters can be found on internet page www.abb.com/lowvoltage by clicking “Online Product Selection Tools” and “Coordination tables for motor protection.

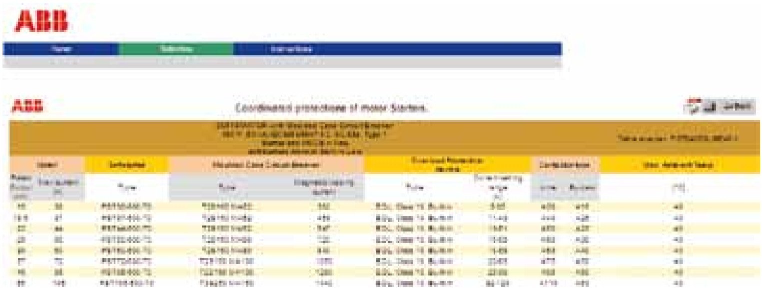
When opening up the coordination tables, the following screen will appear:

To find the correct coordination tables, simply make the selections in the top part of the screen. The selections that are relevant for softstarters are described below:

Protection devices	Fuses (standard or semiconductor) MCCB MMS
Starting type	Softstarter Normal Start In Line Softstarter Normal Start Inside Delta
Voltage (V)	Rated operational voltage for the application
Iq (kA)	Short circuit current rating
Coordination type	Type 1 or Type 2
Motor kW	Rated motor power range

How to read the coordination tables

Depending on the selection, a coordination table similar to the one below will appear.



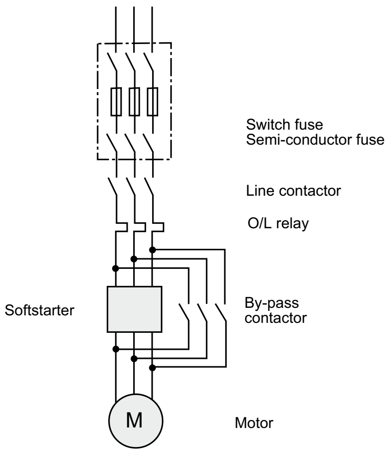
Motor	Indicates the rated output of the motor and maximum current. If this does not correspond fully to the actual motor, select according to the maximum current.
Softstarter	Indicates suitable softstarter type and size for this motor.
Moulded Case Circuit Breaker	Indicates the type and magnetic tripping current for the MCCB.
Switch fuse	Indicates the rated current and type of the fuses as well as the suitable switch fuse for those fuses.
Manual Motor Starter	Indicates the type of manual motorstarter, the magnetic tripping current and the current setting range.
Overload protection device	Indicates the type and setting range for external or built-in overload protection.
Line contactor	Indicates suitable line (main) contactor for the motor. This contactor is given with AC-3 rating.
By-pass contactor	Indicates suitable by-pass contactor. The by-pass contactor is however not required for the coordination. This contactor is given with AC-1 rating.
Max. Ambient Temperature	Indicates the maximum allowed temperature for the coordination.

Coordinations

Starter and fuses In-line

The coordinations with the devices In-line are based on this circuit diagram.

Note that the by-pass contactor is not required for the coordination.

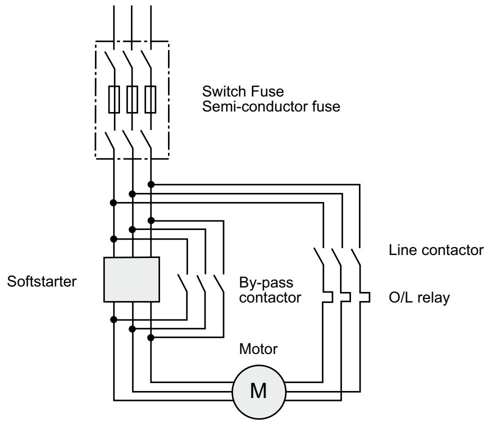


Starter and fuses In-line
Line contactor AC-3
By-pass contactor AC-1

Starter Inside Delta and fuses In-line

The coordinations with the softstarter Inside Delta are based on this circuit diagram.

Note that the by-pass contactor is not required for the coordination.



Starter inside delta and fuses In-line
Line contactor AC-3
By-pass contactor AC-1
Line contactor and by-pass contactor Inside Delta connected

In many softstarters the O/L relay is integrated.

When using PSTB softstarters, the fuses are placed inside the delta. Contact ABB for more information.

Environmental information

How a product affects the environment is a matter that is becoming more and more important when designing new products today but also when updating existing product ranges. ABB puts big efforts into reducing the environmental impact from all ABB products.

RoHS (Restriction of Hazardous Substances)

RoHS is a directive that specifies which substances are not allowed to be used in certain products. The RoHS directive mainly concerns consumer products, and softstarters are not covered by this legislation. Despite this, many of the ABB softstarters do comply with the RoHS directive.

Harmonics

Harmonics are unwanted voltages and currents existing in almost every electrical system today and are always a multiple of the rated frequency.

Typical harmonics are 3rd, 5th, 7th, 9th etc. The harmonics contribute to the unnecessary heating of motors, cables and other equipment and may shorten the life of these devices if exposed for a long period of time.

It can sometimes also disturb functions in electronics and systems. The harmonic contents and the level naturally depend on the source but also on several other parameters such as the impedance in the feeding network, the motor, capacitors and other devices used in the system altogether - in other words a quite complex phenomenon.

Harmonic content and softstarters

The question of harmonic content for softstarter applications is actually in general not relevant at all. These reflections usually come from variable speed drive applications where harmonics are generated continuously and a filter is always required in public networks and very often used also in industrial networks. With our softstarters we fulfil the EMC directive concerning emission and immunity and there is no need for any particular actions regarding this matter at all.

Frequently asked questions (FAQ)

Main contactor

Q Is there any requirement to put a main contactor in series before the softstarter?

A The softstarter does not require any main contactor but we recommend the use of one for emergency stop and/or trip of the overload relay. In some applications an MCCB can be used instead of the main contactor.

Ambient temperature

Q Can I use a softstarter if the ambient temperature is higher than the recommended value during operation?

A The softstarter can normally be operated at a higher ambient temperature during operation if the rated curent for the unit is derated according to the manufacturer's recommendation.

Soft stop applications

Q What applications are suitable for soft stop?

A Pumps and conveyor belts loaded with fragile products are the two main applications suitable for soft stop.

Advantages of by-pass

Q What are the advantages of using by-pass?

A Reduction of power loss. It is also possible to reduce the enclosure size and use a higher IP-class since air ventilation is not required.

Power loss

Q What is the power loss of a softstarter during a continuous run?

A The values can normally be found in the catalogue. For ABB softstarters the following formula can be used (for example for PST30...300):
$P_{Ltot} = [3 \times I_e \times 1.0] + 50$ (W)
This value is reduced to 50 W only when using a by-pass. This is the power of the cooling fans, circiut boards etc.
I_e is the operational current of the motor.

Resistive loads

Q Can the softstarter work on capacitive loads or resistive loads?

A No, all ABB softstarters are only designed to be used for inductive loads.

Capacitor banks

Q Where shall capacitor banks for power factor compensation be placed when using softstarters?

A Capacitor banks can not be placed between the softstarter and the motor since this may damage the softstarter. Instead the capacitor banks are placed on the line side of the softstarter.

Utilisation category

Q What utilisation category should be used for the main contactor and the by-pass contactor?

A Main contactor: always use AC-3.
By-pass contactor: it is possible to use AC-1.

Frequently asked questions (FAQ)

Fault indication when starting

Q Why does the softstarter indicate a fault when the start signal is given to the main contactor and softstarter at the same time?

A If the main contactor is closed too late the softstarter will indicate this as a phase loss fault. Delay the start signal to the softstarter by approx. 0.5 sec. to solve this phenomenon.

Test without motor

Q Can I test a softstarter without using a motor?

A No, this is not possible since there will be no current going through the softstarter and some types will also indicate loss of load.

Overload relay trips during start

Q Why does the overload relay trip during start?

A Possible reasons can be one of these or in a combination:

- too low current limit
- too long ramp time
- too low initial voltage
- wrong tripping class on the overload
- wrong setting on the overload

Separate overload relay when using by-pass

Q Do I need a separate overload relay when using a softstarter with built-in electronic overload and by-pass?

A If the current transformers of the softstarter can be installed so that the measuring can be performed when by-passed a separate relay is not required; otherwise yes.

Different frequency

Q Can I use the same softstarter at both 50 and 60 Hz?

A It is possible with all type of ABB softstarters as long as the curve is sinusoidal.

Voltage fluctuations

Q What voltage fluctuations are allowed for the softstarters?

A The minimum and maximum value where we can guarantee full function is -15% to + 10% of the rated value. This is also stated in the IEC-standar

Example: PSR25-600-70. The operational voltage for this product is 208 V ... 600 V e.g. 208 V - 15% ... 600 V + 10%.

Semi-conductor fuses

Q Do I always have to use semi-conductor fuses?

A When using semi-conductor fuses a type 2 coordination can be achieved. It is possible to use an MCCB (moulded case circuit breaker) or MMS (manual motorstarter) instead but then with a type 1 coordination. For a more in-depth description see the chapter on coordination.

Quantites and units

Length

yd	=	yard
m	=	metre
mm	=	millimetre
cm	=	centimetre
in	=	inch
ft	=	feet
km	=	kilometre

Time

h	=	hour
min	=	minute
s	=	second

Weight

oz	=	ounce
ib	=	pound
kg	=	kilogram
g	=	gram

Power / Energy

hp	=	horse power
W	=	watt
kW	=	kilowatt
kWh	=	kilowatt-hours

Volume

l	=	litre
ml	=	millilitre
cu in	=	cubic inch
cu ft	=	cubic feet
gal	=	gallon
fl oz	=	fluid ounce

Electrical

A	=	Ampere
V	=	Volt
W	=	Watt
Ω	=	Ohm
F	=	Farad

Formula and conversion factors

In this chapter some useful formula and conversion factors are found.

The formulas are used for calculating, for example, rated motor torque, moment of inertia, flywheel mass, etc.

The conversion factors are used to convert for example kW to hp, Celsius to Fahrenheit, km/h to miles/hour, etc.

Ohms Law

$I = \frac{U}{R}$ $R = \frac{U}{I}$ $U = I \times R$

I = Current (ampere)

U = Voltage (volt)

R = Resistance (ohm)

Rated motor torque

$$M_r = \frac{9550 \times P_r}{n_r}$$

M_r = Rated torque, Nm

P_r = Rated motor power, kW

n_r = Rated motor speed, rpm

Moment of inertia

$$J = \frac{m(R^2 + r^2)}{2}$$

J = Moment of inertia , kgm^2

m = Mass for the flywheel, kg

R = Outer radius, m

r = Inner radius, m

Flywheel mass

mD^2 or GD^2 ($mD^2 \sim GD^2$)

mD^2 = Flywheel mass, kpm^2

GD^2 = Flywheel mass, kgm^2

Relation Moment of inertia and Flywheel mass

$$J = \frac{1}{4} GD^2 = \frac{1}{4} mD^2$$

J = Moment of inertia, kgm^2

mD^2 = Flywheel mass, kpm^2

GD^2 = Flywheel mass, kgm^2

Moment of inertia on load shaft recalculating to the motor shaft

$$J'_b = \frac{J_b \times n_b^2}{n^2}$$

J'_b = Moment of inertia recalculated to the motor shaft, kgm^2

J_b = Moment of inertia for the load, kgm^2

n_b = Speed of the load, rpm

n_r = Speed of the motor, rpm

Loaded torque on load shaft recalculated to the motor shaft

$$M'_b = \frac{M_b \times n_b}{n_r}$$

M'_b = Load torque recalculated to the motor shaft, Nm

M_b = Load torque, Nm

n_b = Speed of the load, rpm

n_r = Speed of the motor, rpm

Electrical Power

$$P = \frac{U \times I \times PF}{1000} \quad \text{(1-phase)}$$

$$P = \frac{U \times I \times PF \times \sqrt{2}}{1000} \quad \text{(2-phase)}$$

$$P = \frac{U \times I \times PF \times \sqrt{3}}{1000} \quad \text{(3-phase)}$$

P = Power in kW

PF = Power Factor

Conversion factors

Length

1 mile	=	1.609344 km	**1 km**	=	0.621 mile
1 yd	=	0.9144 m	**1 m**	=	1.09 yd
1 ft	=	0.3048 m	**1 m**	=	3.28 ft
1 in	=	25.4 mm	**1 mm**	=	0.039 in

Velocity

1 knot	=	1.852 km/h	**1 km/h**	=	0.540 knot
1 mile/h	=	1.61 km/h	**1 km/h**	=	0.622 mile/h
1 m/s	=	3.6 km/h	**1 km/h**	=	0.278 m/s

Area

1 acre	=	0.405 ha	**1 ha**	=	2.471 acre
1 ft^2	=	0.0929 m^2	**1 m^2**	=	10.8 ft^2
1 in^2	=	6.45 cm^2	**1 cm^2**	=	0.155 in^2

Volume

1 ft^3	=	0.0283 m^3	**1 m^3**	=	35.3 ft^3
1 in^3	=	16.4 cm^3	**1 cm^3**	=	0.0610 in^3
1 gallon	=	4.55 l (UK)	**1 l**	=	0.220 gallon (UK)
1 gallon	=	3.79 l (US)	**1 l**	=	0.264 gallon (US)
1 pint	=	0.568 l	**1 l**	=	1.76 pint

Mass

1 lb	=	0.454 kg	**1 kg**	=	2.20 lb
1 oz	=	28.3 g	**1 g**	=	0.0352 oz

Torque

1 Nm	**=**	0.101kgm	**1 kgm**	=	9.806 Nm

Moment of Inertia

1 Nm^2	=	2.42 ft.-lb^2	**1 ft.-lb^2**	=	0.41322 Nm^2
1 kgm^2	=	0.2469 ft.-lb^2	**1 ft.-lb^2**	=	4.0537 kgm^2
1 oz.-in^2	=	0.000434 ft.-lb^2	**1 ft.-lb^2**	=	2304.147 oz. in^2

Force

1 kp	=	9.80665 N	**1 N**	=	0.102 kp
1 lbf	=	4.45 N	**1 N**	=	0.225 lbf

Energy

1 kpm	=	9.80665 J	**1 J**	=	0.102 kpm
1 cal	=	4.1868 J	**1 J**	=	0.239 cal
1 kWh	=	3.6 MJ	**1 MJ**	=	0.278 kWh

Power

1 hp	=	0.736 kW	**1 kW**	=	1.36 hp
1 hp	=	0.746 kW (UK; US)	**1 kW**	=	1.34 hp (UK; US)
1 kcal/h	=	1.16 W	**1 W**	=	0.860 kcal/h

Temperature

0 ^{o}C	=	32 ^{o}F
^{o}C	=	5 / 9 (^{o}F -32)
0 ^{o}F	=	-17.8 ^{o}C
^{o}F	=	9 / 5 (^{o}C +32)

Glossary

AC	Alternating current.
Active power	The power consumed by the motor which is converted into mechanical action.
Ambient temperature	Ambient temperature is the temperature of water, air or surrounding medium where the equipment is used or stored.
Apparent power	The total power consumed by the motor. Consists of both the active power and the reactive power.
Asynchronous speed	The speed of an AC induction motor at full load and full voltage, also defined as the rated speed.
Bearing	A component used to reduce the friction and wear between rotating devices.
By-pass	A by-pass contactor is used to by-pass another device, for example a softstarter to reduce the power loss.
Control supply voltage	The voltage that supplies, for example, the softstarter.
Control circuit voltage	The voltage used to control (start/stop) the softstarter.
Cos phi	See power factor.
CSA	Canadian Standard Association.
Current limit	An electronic method to limit the starting current to the motor during start up. It is normally possible to adjust the function so that the motor torque will be high enough to take off.
Cycle	A sequence of operations that is repeated regularly or the time it takes to complete one operation.
D-end	The end that is normally the drive end of an electrical motor.
DC	Direct current.
Degree of Protection	Defined and stated as IP (International Protection) class indicating the degree of protection against contact and penetration of solid objects and water.

Delta connection The connection type of a motor where the windings are connected in a delta.

Derating When a device has to be operated with reduced ratings (normally the current) due to high ambient temperature or high altitude.

DOL Direct on line. A common starting method.

Duty Cycle The total cycle from one start to the next, including ramp time for start and stop, operation and pause time, if any.

Efficiency The ratio between mechanical output and electrical input. The percentage given indicates how effective the motor is at converting electrical energy to mechanical energy.

EMF Electromotive Force, another term for voltage or potential difference, for example, the voltage generated by a motor.

EPD Environmental Product Declaration, a description of how a specific product affects the environment.

ESD Electro Static Discharge.

Fault Any malfunction that occurs and interferes with normal operation.

FBP FieldBusPlug – Using the FieldBusPlug it is possible to select between several different fieldbus protocols.

Flywheel mass The total mass (mD^2 or GD^2) of a rotating body normally given in kpm^2 or kgm^2. The value of the flywheel mass is 4 times the moment of inertia.

Frequency The number of periodic cycles per unit of time.

Gate The control element of a SCR (thyristor).
When giving a small positive voltage to the SCR it will start conducting.

Glossary

Heatsink	A component often made of aluminium used to get rid of the heat inside an electrical device generated by the current.
Heavy Duty Start	A start with a load that has a high or very high moment of inertia. A starting time DOL of more then 5 seconds can be defined as a heavy-duty start.
IEC	International Electrotechnical Commission which is part of the International Standard Organisation.
Inertia	A measure of a body's resistance to change in velocity whether the body is moving at a constant speed or is at rest. The velocity can be rotational or linear.
Induction motor	An AC motor with a primary winding (usually the stator) connected to the power supply and a secondary winding (usually the rotor) carrying the induced current.
In-Line connection	A connection type where the devices in the main supply are connected in series with each other.
Inside Delta connection	A connection type where the devices are connected inside the motor delta circuit. The current is reduced to $1/\sqrt{3}$ = 58% compared with the line current.
Integrated Circuit (IC)	A small electronic unit that can consist of thousands of transistors usually mounted on a PCB.
Intermitens factor	The relation between how long a machinery is working (ON time) and how long it is resting (OFF time) in a cycle.
Jog	Momentary moving of the motor by repetitive closure of a circuit using a contact element or a pushbutton.
LCA	Life Cycle Assessment, an analysis of how a product affects the environment from ”cradle to grave”.
LCD	Liquid Crystal Display, a readout interface used in digital watches, laptop computers and some softstar-ters.

LED	Light-emitting diode.
Load torque	The braking torque on the motor shaft caused by the load. If the braking torque is equal or nearly equal to the rated motor torque it can be defined as high load torque.
Locked Rotor Current	The current taken from the line when a rotor is at a standstill at rated voltage and frequency. It is the line current when starting the motor direct.
Megger Test	This is normally measured in megohms using full voltage with low current and is used to measure the resistance in an insulation system. It can be used for checking the thyristors, for example.
Micro processor	A central processing unit utilising large-scale integration technology.
MCCB	Moulded Case Circuit Breaker
MMS	Manual Motor Starter
N-end	The end that is normally the non-drive end of an electrical motor.
NEMA	The National Electrical Manufacturers Association (USA)
Network	A number of nodes connected to each other with some type of communication medium. A network can be of single link type or multiple link type.
Noise	Unwanted disturbances in a communication medium that tend to obscure the data content.
Nominal current	The nominal current is the current drawn by a fully loaded motor at its specified nominal speed.
Nominal speed	See asyncronous speed.
Nominal torque	The torque of the motor when running at nominal speed.

Glossary

Normally Closed Contact (NC)	A contact or set of contacts that are closed when the relay or switch is de-energised. The contact(s) open when a relay or switch is energised.
Normally Open Contact (NO)	A contact or set of contacts that are open when the relay or switch is de-energised. The contact(s) close when the relay or switch is energised.
Normal Start	A start with a load that has small or medium high moment of inertia. A starting time DOL of less than 5 seconds can be defined as normal start.
Operational voltage	The voltage that is fed to the motor, usually 3-phase.
Overload relay	A device used to avoid overheating of the motor. Can be of electronic or thermal type.
Parallel start	Parallel start of motors is normally when two or more motors are started at the same time with the same starting equipment.
PCBA	Printed Circuit Board Assembly are the circuit boards inside the softstarter.
PLC	Programmable Logic Controller, consists of a central processor, input/output interfaces and a memory designed as an industrial control system. A PLC system is used for the storage of instructions, timing, counting, report generation, I/O control and more.
Power	Work done per unit of time measured in horsepower (hp), watt (W) or more commonly kW.
Power Factor	The phase difference measured between the voltage and the current in an AC circuit represented by the cosine angle.
Protocol	A set of conventions governing the format and timing of data between communication devices.
Rated current	See nominal current.
Rated speed	See asynchronous speed.

Rated torque	See nominal torque.
Reactive power	The power consumed by the motor which is used for the magnetization of the motor.
Reversing	Changing of the rotation direction of the rotor or motor armature.
SCR	Silicon Controlled Rectifier often referred to as a thyristor. See thyristor.
Semi-conductor fuses	A special type of high-speed fuse used as thyristor protection since normal (gG/gL or aM) fuses are not fast enough.
Sequential start	Sequential start of motors is normally when two or more motors are started one by one in a sequence with the same starting equipment.
Serial Communication	The way of transmitting data in a network between different nodes, using some type of protocol.
Slip	The difference (usually expressed in percentage) between the synchronous speed and the rotor speed of an AC induction motor.
Star connection	The connection type where each winding in a polyphase circuit is connected at one end to a common point.
Synchronous speed	The speed of the rotating magnetic field on an AC induction motor determined by the frequency and the number of magnetic poles in each phase of the stator windings.
Thyristor	A solid-state switch that has an anode, cathode and a control element called the gate, which makes it possible to turn it on at will. It can rapidly switch large currents at high voltages.
Tripping class	The tripping class defines the starting time at a specific current before tripping occurs. Different classes exist, for example 10, 20, 30 etc. where class 30 allows the longest starting time.

Glossary

Torque control	A way for a softstarter to control the motor torque instead of the voltage.
Uc	Control circuit voltage
U_e	Operational voltage
U_s	Control supply voltage
UL	Underwriters Laboratories (an approval agency).
Y connection	See Star connection.

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